Musquash Ecosystem Framework Development Progress to date

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ABSTRACT

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Fisheries and Oceans Canada has identified a need for the development of an ecosystem framework as a core element in the management plan for the Musquash Marine Protected Area (MPA). Chapter 1 provides information on the concept of the ecosystem framework. Such a framework establishes physical, chemical, and biological habitat parameters for the assemblage of species using a defined physical area. It assists in setting boundary or trigger levels for each parameter in order to establish ideal and recoverable ranges, which must be maintained in order to protect or restore various ecological relationships. By maintaining and restoring these physical and biological relationships, the vision and broad ecosystem objectives for the MPA will be achieved including maintaining species diversity, maintaining ecological integrity, and protecting diverse habitats. The framework will not necessarily identify what activities may and may not take place. It would provide managers with a grounded means for assessing risk associated with individual activities, and defending a position taken regarding the decisions made concerning an activity. The framework provides an ecosystem-based way to consider cumulative impacts, however, managers will still have to define what risks are acceptable. In order to proceed with this framework several identified tasks need to be completed. Information acquired from the execution of some of these tasks are present in Chapter 2. The different ecotypes in the MPA are identified and mapped. All the biological components within each ecotype are identified. A series of tables present species lists and life history information on selected species within each of the identified ecotypes. Experts were invited to a workshop to provide feedback on the identification of indicator species for each ecotype in the MPA. Several species were identified and recommendations were made on how to proceed in identifying other indicator species. Finally, the remaining steps in the framework development are identified.

RÉSUMÉ

R. Singh and M-I. Buzeta (eds.), 2005. Musquash Ecosystem Framework Development. Progress to date. Can. Manuscr. Rep. Fish. Aquat. Sci. 2727: x + 202 pp.

Pêches et Océans Canada a estimé nécessaire d'élaborer un cadre écosystémique, devant constituer un élément principal du plan de gestion de la zone de protection marine (ZPM) de la Musquash. Le chapitre 1 fournit des renseignements sur le concept de cadre écosystémique. Un tel cadre définit les paramètres physiques, chimiques et biologiques de l'habitat de l'assemblage d'espèces d'une zone donnée. Il sert à déterminer la limite ou seuil de déclenchement applicable à chaque paramètre afin d'établir des fourchettes de valeurs idéales ou récupérables, qu'il faut maintenir pour protéger ou rétablir diverses relations écologiques. En maintenant ou en rétablissant ces relations écologiques, on réussira à réaliser la vision et les grands objectifs écosystémiques établis pour la ZPM, notamment le maintien de la biodiversité et de l'intégrité écologique et la protection des divers habitats. Le cadre écosystémique n'indiquera pas nécessairement quelles activés peuvent ou ne peuvent pas

avoir lieu. Il donnera au gestionnaire un moyen empirique d'évaluer les risques associés à chaque activité et de défendre la décision qui sera prise au sujet d'une activité. Le cadre place dans une perspective écosystémique l'analyse des effets cumulatifs, mais il laisse aux gestionnaires le soin de déterminer quels risques sont acceptables. L'adoption de ce cadre nécessite l'exécution préalable de plusieurs tâches, qui sont définies. L'information provenant de l'exécution de ces tâches est décrite au chapitre 2. Les divers écotypes présents dans la ZPM sont cernés et représentés. Toutes les composantes biologiques de chaque écotype sont définies. Une série de tableaux présente les listes des espèces et nous renseigne sur le cycle biologique de certaines espèces de chaque écotype défini. Des experts ont été invités à participer à un atelier pour donner leur avis sur le choix d'espèces indicatrices pour chaque écotype de la ZPM. Plusieurs espèces ont été retenues et des recommandations ont été formulées sur la façon de procéder pour sélectionner d'autres espèces indicatrices. Les étapes restantes de l'élaboration du cadre sont décrites.

GENERAL INTRODUCTION

Fisheries and Oceans Canada has identified a need for the development of an ecosystem framework as a core element in the management plan for the Musquash Marine Protected Area. An ecosystem framework establishes physical, chemical, and biological habitat parameters for the assemblage of species using a defined physical area. Boundary or trigger levels can be set for each parameter to establish ideal and recoverable ranges, which must be maintained in order to protect or restore various ecological relationships. By maintaining and restoring these physical and biological relationships, the vision and broad ecosystem objectives for the MPA will be achieved including maintaining species diversity, maintaining ecological integrity, and protecting diverse habitats. This document summarizes the ongoing development of an Ecosystem Framework towards the management of Musquash as a Marine Protected Area.

Chapter 1 provides information on the concept of the ecosystem framework and identifies the necessary information required to guide managers in risk assessment associated with various activities within the MPA. It lists a series of tasks that should be completed in order to develop the framework.

Chapter 2 provides information on some of the tasks identified in Chapter 1. The different ecotypes in the MPA are identified and mapped. A series of tables present species lists and life history information on selected species within each of the identified ecotypes. Results are presented from a workshop to which experts were invited in order to provide feedback on the identification of indicator species for each ecotype.

CHAPTER 1

Development of a Musquash Ecosystem Framework

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(September 2003)

Introduction

Fisheries and Oceans Canada has identified a need for the development of an ecosystem framework as a core element in the management plan for the Musquash Marine Protected Area (MPA). An ecosystem framework establishes physical, chemical, and biological habitat parameters for the assemblage of species using a defined physical area. Boundary or trigger levels can be set for each parameter to establish ideal and recoverable ranges, which must be maintained in order to protect or restore various ecological relationships. By maintaining and restoring these physical and biological relationships, the vision and broad ecosystem objectives for the MPA will be achieved including maintaining species diversity, maintaining ecological integrity, and protecting diverse habitats.

Many components necessary to build an ecosystem framework currently exist for the Musquash Estuary. This includes a wealth of scientific research on a wide array of species, water chemistry, and habitats. Such information should allow for the development of an ecosystem framework that can be immediately effective for managers in guiding and defending decisions regarding use of the protected area. It is clear that there will be a need to collect additional ecological information in some areas, and for some species. However, with the amount of existing information, it likely will be possible to collect the required data as part of either the approval process, or ongoing monitoring and mitigation, for an identified activity.

An ecosystem framework does not necessarily identify what activities may and may not take place. The framework does provide managers with a grounded means for assessing risk associated with individual activities, and defending a position taken regarding the decisions made concerning an activity. The framework provides an ecosystem-based way to consider cumulative impacts, however, managers will still have to define what risks are acceptable.

This Chapter provides a strategy, through a series of steps, for the development of an ecosystem framework specifically designed for the future management of the Musquash Marine Protected Area. Such a framework is intended to provide users and the public with a clear image of the key ecological relationships in the Musquash estuary. The ecosystem framework will allow activity proponents to know what impact limitations they must meet. For managers, the ecosystem framework will guide various decisions to be made regarding the use of the Musquash protected area, and will demonstrate the ecological importance and relevance of those decisions.

1.0 Scope of MPA Management Approaches

There have been many views on how to manage a Marine Protected Area under the *Oceans Act*. These have been expressed over the years, and range from the early view of an economically viable multiple use area, managed with ecosystem protection in mind, to the more recent view of highly protected ecosystem with only limited uses allowed, usually for current social or economic reasons. The latter is to be within the context of a surrounding ecosystem based integrated management initiative, which allows activities if they do not compromise the sustainability of the living marine resources.

This approach of integrated management with a non-compromising ecosystem base has now come close to the original view of Marine Protected Areas. Recent DFO Policy Committee presentations on oceans management emphasized the establishment of Marine Environmental Quality objectives which would be met through the use of guidelines, standards, and if required, enforced by regulations. There are to be no compromises in meeting the environmental objectives. This places Marine Protected Areas at the extreme end of the protection spectrum.

The proposed Musquash Regulations establish an MPA boundary and three internal management zones in which different activities may be permitted, provided that they do not compromise the overall conservation objectives of the MPA. The Regulations contain a general prohibition on the disturbance, damage, destruction or removal of any living marine organism or any part of its habitat within the MPA. In addition, the Regulations prohibit the depositing, discharging or dumping of substances within the MPA that are likely to result in the disturbance, damage, destruction, or removal of any living organisms or any part of its habitat within the MPA.

The proposed Regulations will permit certain activities such as scientific and educational activities that do not compromise the conservation goals. Moreover, certain activities such as monitoring may be required to support the management and protection of the MPAs, while other activities may be required for specific overriding purposes, such as public safety and security. Within the Regulations, activities are managed through 1) the submission and approval of plans for specified activities according to conditions; and 2) specific exceptions to the general prohibitions according to specified conditions.

MPA regulations of this second type also add the power to review activities and provide for management decisions, made by the Minister, based on the criteria set in the regulations prohibition. Activities are allowed if their impact is not disturbing, disrupting or destroying the marine ecosystem or removing living organisms. This type of decision-making requires some rules and guidance based on the ecosystem in the MPA, and provides the main reason for an ecosystem framework.

The regulatory approach used for Musquash allows for greater flexibility in management and allows for a broader range of activities in a multiple use situation like Musquash. The integrated management approach incorporates the potential to limit the extent of excepted activities if they become more intense and compromise the ecological objectives of the MPA. This puts more weight on the need for a robust ecosystem framework with measurable guidelines upon which to make decisions. Many of the impacts on the MPA's ecosystem may come from outside the MPA boundaries. These activities will be managed through various integrated management processes but in each case DFO will have to provide a strong and rational ecological basis for their intervention in the project. This again requires a strong ecosystem framework to support decision-making.

2.0 Management Functions of the Ecosystem Framework

At the core of an *Oceans Act* MPA is the protection of the marine ecosystem, its living organisms, and their habitats. It is through this filter that all management aspects must pass. This includes policy, programs, scientific studies, activity management, and prosecutions.

Preserving the natural biodiversity of the MPA is of prime concern. This framework preserves diversity by basing ecozone habitat requirements on a broad assemblage of species at all trophic levels during each season. The assumption is that using this broad base will define habitat conditions in ranges suitable for the full community of organisms living there. In addition to the physical/chemical habitat parameters consideration is given to food web balance and the maintenance of natural population profile for harvested species. The food web and harvest levels suitable for support of other species are an area of the framework which will require more research and consideration. At this time the basics can be noted and direction provided for filling in this important aspect.

No matter which management approach is taken in Musquash, an ecosystem framework will be required to support prosecutions under the general regulations, to monitor the health of the ecosystem, and to conduct performance reviews to see if the MPA is meeting its objectives. An ecosystem framework supports all these requirements because it adds definition in measurable terms to what is meant by the proposed regulatory intent:

- Disturb, damage or destroy, or remove from the area any marine organism or its habitat.
- Disturb, damage, destroy, or remove from the Area, any part of the seabed
- Carry out any activity on the surface of the water or in the water column that is likely to result in the disturbance, damage, destruction or removal of any marine organism to its habitat
- Deposit, discharge or dump or cause to be deposited, discharged or dumped any substance on the surface of the water, into the water column or on the seabed

Given that the ecosystem framework provides definition in terms of individual physical, chemical, and biological habitat parameters for specific clearly defined locations (ecozones), then management decisions will be relatively easy and clear to all stakeholders. If the criteria for these decisions are made public in a management plan, then proponents can see what requirements they have to meet and will be less likely to propose non-compliant projects, thereby reducing the management workload.

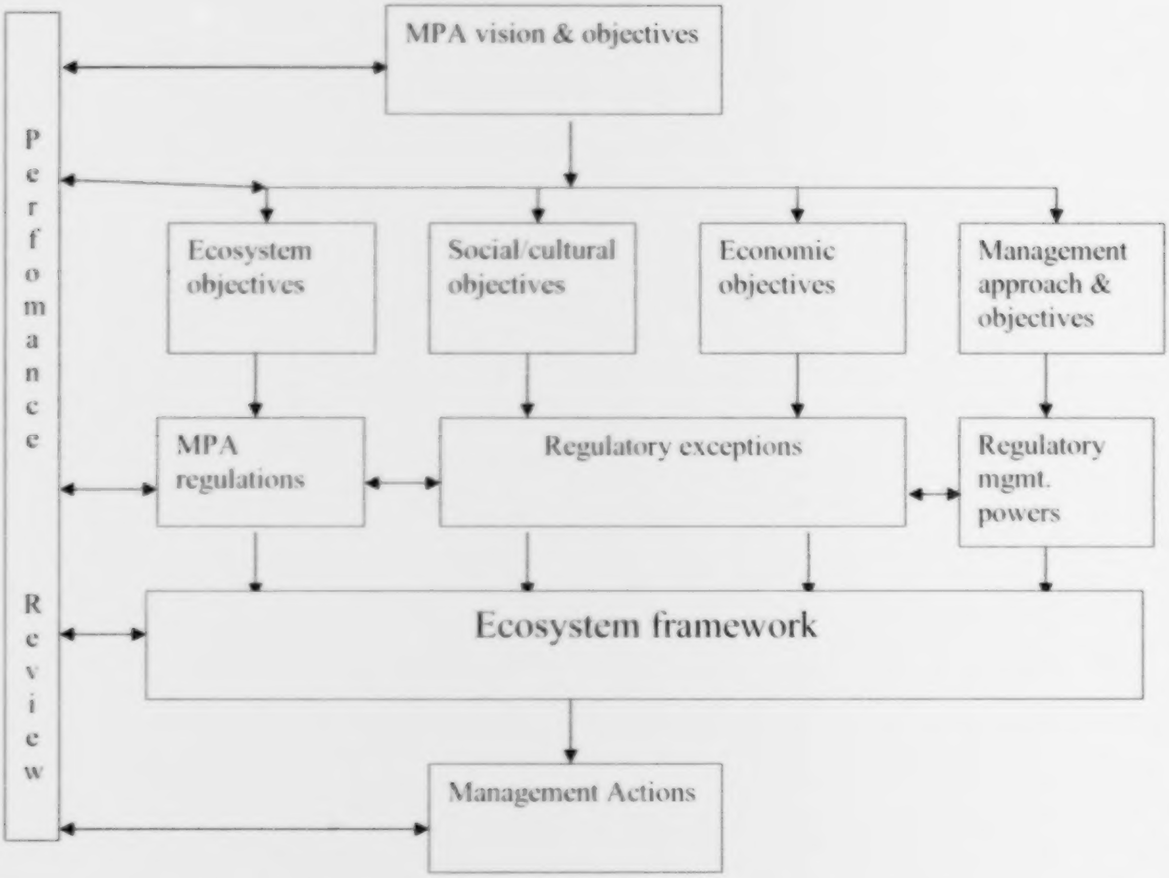
Performance Review
MPA vision & objectives
Ecosystem objectives
Social/cultural objectives
Economic objectives
Management approach & objectives
MPA regulations
Regulatory exceptions
Regulatory mgmt. powers
Ecosystem framework
Management Actions

Fig. 1.1. The ecosytem framework and its relationship to other management requirements.

The ecosystem framework will support DFO court cases. Given a general prohibition for an MPA, the Crown has to prove the prohibition has been violated. Experts will be called to testify that the ecosystem of the site has indeed been "disturbed", as is the intent of the regulation. Any doubt or hedging in this testimony is the favour of the defendant. The best way to protect against a lengthy trial with a stream of scientists testifying for both sides is for DFO to clearly define in advance what is meant by these terms, and to make the measurable parameters levels or ranges public. This approach will also help protect against a due diligence defence which is commonly used where the definition is unclear. The courts will generally support a well thought out framework, with defensable guidelines as proof of a violation if it has been public.

MPAs are designed to protect the marine ecosystem. This is central to any management plan from both DFO's and the community's viewpoint, and should be clearly stated through broad ecosystem objectives. Therefore, all management policies, programs, or activities must pass through some ecosystem objectives filter which is clear to all interested parties before they can be implemented. This ensures the ecosystem objectives in the management plan will be met. To be clear and effective, an ecosystem framework has to be central to the management plan, and all other aspects of the plan must pass through an ecosystem review (See Fig. 1.1). From the framework comes the rules or ecosystem standards against which all activities are compared. The framework thereby provides a reference for DFO staff and the MPA management body to refer to when developing management plans, policies or actions. If an activity contradicts any of the rules it would either be modified, halted, or a review process initiated to consider revision of the rules. Revision would require the presentation of scientific advice to the management body and DFO that clearly shows there would not be a violation of the standards set by the MPA regulations.

The primary management goal for the MPA presented by the Musquash Planning Group is "to have activities better regulated, and that existing laws and regulations should be followed" [1]. Similarly, the community vision for the Musquash MPA initiative is reflected in the statement below.

> "Protection and Restoration of the Musquash Estuary and surrounding Salt Marshes."
> *Source: Musquash MPA Planning Group*

Additional objectives proposed by the Planning Group are:

- Maintaining biodiversity of the area
- Maintaining a healthy fishing industry
- Protecting this highly productive habitat
- Increasing natural habitat and bird life in the marsh and surrounding land
- Preserving the area for future generations
- Ensuring conservation and sustainable use of the marsh

From a DFO, point of view, the draft Regulatory Impact Assessment Document (RIAS) sets out how Musquash meets the reasons for establishment as an MPA under the *Oceans Act* (Table 1.1). DFO will have to report on how successful they have been in achieving the reasons for designation in performance measure documentation. An ecosystem framework will help make the link between ecosystem-based reasons and measures showing management success.

All this results in a combined ecosystem based vision for the area as it applies to the *Oceans Act* regulations and management. Other objectives for ecosystem protection, social, and economic aspects will be included in the management plan and implemented through other laws, regulations and processes.

Table 1.1. *Oceans Act* (Section 35) reasons and relevant Musquash charactertitics for MPA Designation (as presented in Fisheries and Oceans, 2002.).

***Oceans Act* Reasons**	**Musquash Estuary characteristics**
a) Commercial and non-commercial fisheries, including marine mammals and their habitats	Coastal habitats such as estuaries serve as important habitats for a variety of commercial and non-commercial species, e.g. juvenile fish areas, food sources. Several commercial species are found within the Musquash area. The linkages between estuaries and critical life stages (larval and juvenile stages) of commercial and non-commercial species is well established. Estimates that 2/3 species harvested are "estuarine dependent" at some stage in their life. Several species live their entire lives in estuarine waters.
b) Threatened or endangered species	No species currently listed under COSEWIC and the pending Species at Risk legislation depend on the estuary.
c) Unique habitats	Musquash area 'unique' among estuaries in the Bay of Fundy given its large size and its relatively undisturbed condition. It is the largest estuarine habitats with extensive marsh areas west of the upper Bay of Fundy. Eighty-five percent of wetland areas in the Bay of Fundy have been modified.
d) Marine areas of high biodiversity or biological productivity	Estuaries are recognised as one of the most important and productive ecosystems in our coastal waters, providing a valuable food and nutrient export function. The diverse habitats of Musquash support a diversity of life, ranging from invertebrate communities to high populations of a number of juvenile fish and birds.
e) Any other marine resource or habitat as is necessary to fulfil the mandate of the Minister of Fisheries and Oceans	The project provides excellent scientific research and on-site education development opportunities. The proximity to St. Andrews Biological Station, the Huntsman Marine Science Centre, the University of New Brunswick, and the city of Saint John enhances this aspect of the initiative and future consideration as a MPA.

Proponents of projects or activities are generally convinced they are not having a negative impact on the ecosystem. However, they seldom have any rules, comprehensive view, or expertise upon which to base such statements, and even formal or consultant based environmental review processes often are without a framework to gauge impact.

A well developed ecological framework, a common approach developed by managers, and a monitoring network will give MPA managers the rules by which to operate. These rules will undoubtedly be modified over time as new scientific studies are done. However, rules can be set and applied based on the best knowledge currently available.

In an MPA the precautionary approach has to be applied to its full extent. If it appears possible projects and activities will exceed any of the bounds set by the ecosystem framework, they will have to be proven innocent of ecosystem impacts in real operational situations elsewhere before they are allowed to occur within the MPA. If a proponent feels the values chosen for the framework are not valid, proof will have to be provided by the proponent from actual field studies before there is a change made.

Where does the framework fit within the Musquash management plan? Fig. 1.2 lists a table of contents for a potential management plan for Musquash based on a December 2001 document provided by DFO. It shows how it could be revised to make the ecosystem framework central to the plan.

It should be noted that the Table of Contents in Fig. 1.2 is developed largely from a DFO ecosystem protection point of view. To be fully integrated the multi-stakeholder committee will need to add other ecological, social/cultural, and economic filters through which management decisions must pass. We have only addressed the DFO MPA management needs for management, which will be the basis of an integrated plan once the regulations are in place.

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PREAMBLE

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- ➢ Biological description of ecotypes
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  - ○ Habitat requirements of each indicator species by season
- ➢ Definition of ecozone criteria (putting the physical habitat together with the biological = ecozone)
- ➢ Ecosystem-based Management criteria (by ecozone and by season as they occur in each management area)

Framework Considerations

Current issues and initiatives vs. ecosystem based management criteria = required management action
- Maintaining and enhancing environmental quality/health
  Issue 1: Changes in environmental quality (water/sediment) – direct discharge of contaminants and runoff from watershed into the estuary
  Issue 2: Changes in water/sediment quality – movement of contaminants into estuary from adjacent coastal waters
  Issue 3: Destruction or deterioration of Benthic Habitat – Effects of Fishing Gear
  Issue 4: Destruction or deterioration of Benthic Habitat – coastal developments/ dredging/infilling
  Issue 5: Destruction or deterioration of Benthic Habitat – Effects of marine plant harvesting
  Issue 6: Destruction or deterioration of Salt marshes/Tidal Flats
  Issue 7: Impacts on environmental quality/benthic habitats from aquaculture
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- Education and awareness
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6.0 Summary of Management Actions
- 1st year plan
- 5-year plan
- 10-year plan

7.0 Next Steps

Appendices

Fig. 1.2. Suggested Musquash Management Plan Table of Contents.

In summary, the ecological framework is required in order to:

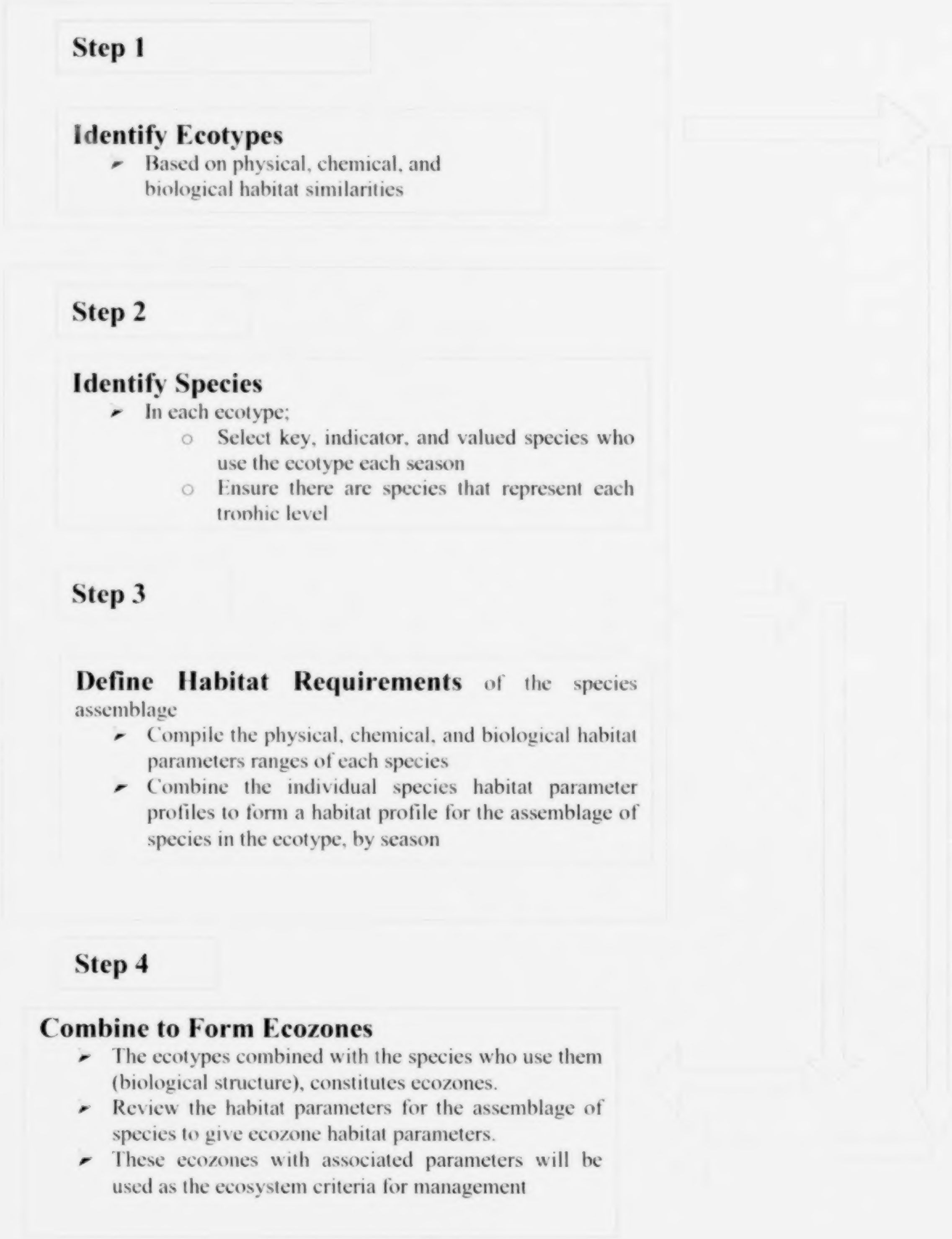
- Support management decisions,
- Streamline management workload,
- Reduce the number of non-compliant proposals,
- Support court cases, expert opinion, and to avoid due diligence defenses,
- Be the central component of a management plan upon which policies, programs and actions are based for an MPA,
- Be the mechanism for performance review of the ecosystem objectives of the MPA.

The framework will serve to:

- Simplify environmental review shortening the timeline for response set at 30 days in the regulation proposal,
- Give proponents rules to follow when designing projects, mitigation plans, and monitoring plans,
- Give a level of certainty to all involved that the ecosystem will be preserved,
- Provide a basis for education and awareness initiatives,
- Clearly set out the rules in support of prosecutions under the regulations,
- Allow anyone to compare any proposed project against the guidelines providing openness and consistency in decision-making.

3.0 How the Framework works

An ecosystem framework is holistic in that it explores all existing habitats and their constituent physical and chemical parameters; it explores all species present and their biological requirements and preferences; it explores the trophic relationships of the species present and their key dependencies on one another. An ecosystem framework is also efficient and effective because it evaluates all habitat and biological knowledge, yet identifies the key/foundation habitats and species, using only these components to make the framework functional, and manageable in size. The objective is to define ecozones of manageable size and set measurable values for the physical, chemical, and biological parameters, which define the optimum habitat for the assemblage of species which live there in each season. There are four basic steps to developing an ecosystem framework (see Fig. 1.3).



Step 1

Identify Ecotypes

- Based on physical, chemical, and biological habitat similarities

Step 2

Identify Species

- In each ecotype;
    - Select key, indicator, and valued species who use the ecotype each season
    - Ensure there are species that represent each trophic level

Step 3

Define Habitat Requirements of the species assemblage

- Compile the physical, chemical, and biological habitat parameters ranges of each species
- Combine the individual species habitat parameter profiles to form a habitat profile for the assemblage of species in the ecotype, by season

Step 4

Combine to Form Ecozones

- The ecotypes combined with the species who use them (biological structure), constitutes ecozones.
- Review the habitat parameters for the assemblage of species to give ecozone habitat parameters.
- These ecozones with associated parameters will be used as the ecosystem criteria for management

Fig. 1.3. Primary steps in the development of an ecosystem framework.

The first step is to carefully define ecotypes (somewhat homogenous habitats) by their physical and chemical habitat features. (Note that physical habitats may encompass unique habitats created by the biological communities present). Various methods for categorizing inshore ecotypes, or littoral zones already exist, and can be used as the basis of this process. In the coastal intertidal area this is done by selecting the visibly different areas defined by common physical properties such as mud flat, beach, etc., or by dominant habitat forming species such as marsh grasses, rockweed, etc. Consideration of water column characteristics such as currents, salinity, and stratification may further be used to delineate ecotypes. These areas can usually be well defined, however, for management purposes, numerous neighboring small patches of various habitat types may be lumped together in one classification.

Once the ecotype components of the framework have been defined; the biological components must be examined, which is the second step in developing the framework. A species list is compiled for each ecotype as complete as possible, noting spatial distribution by both season and by life stage. A review of collected data will identify ecotypes that are critical to individual species, and life stage process such as spawning, rearing, holding, food supply, wintering etc. areas. An evaluation of the trophic relationships, and the predator prey relationships, of the species present will further highlight species that are important foundation food sources supporting the web of species present.

Once the various species and relationships have been defined, a group of key, indicator and valued species are selected. Selection of species is done to represent each trophic level in each season. Key species are ones which dominate, or are bottlenecks in the food web at the trophic level. Indicator species may be selected because they are commonly used in environmental monitoring (i.e. mussels), or because there is a sampling program or data available on their health or density. Valued species may be listed as endangered or threatened, or due to interest for the local community for reasons such as fishing, or people just wanting to know they are there. This selection process is quite flexible and intended to capture both ecologically important species, species with limited habitats, and those of social concern.

At this point the ecosystem framework process has identified and evaluated all ecotype habitats and described the biological life in the ecotype through a representative selection of species covering each trophic level as present in each season. It is appropriate to confirm if sensitive habitats required by the key species selected are fully contained within those ecotypes previously identified for inclusion in the framework. Any that are not must be brought into the framework. This cross evaluation approach of first examining habitats and the species present; and then examining the species present and their key habitats inherently acknowledges the ecological relationships and complexities that exist in the project area. This evaluation may include areas outside of the MPA boundaries which will have to be addressed through integrated management.

The third step in providing a functional ecosystem framework is to specify the individual physical, chemical, and biological habitat parameter boundaries (or "profiles") for each of the selected species. These boundaries are identified from existing measures in the identified ecotypes of the MPA such as research based Marine Environmental Quality guidelines

(MEQ's), Canadian Water Quality Guidelines (WQG's) for the Protection of Aquatic Life [2], Habitat Suitability Index models and species profiles available from near by New England and DFO sources, other similar scientifically defensible guidelines, from literature searches, and expert scientific opinion. These profiles define the controlling habitat parameters for the species. Habitat parameter ranges can be identified as optimum or secondary/recoverable. That is to say, the profiles set acceptable parameter limits, and preferred parameter limits for each selected species of the framework. For an MPA, parameters should be managed within the optimum range which would also be used in the ecosystem framework. For an integrated management area, a slightly less protective approach might be taken, allowing some parameters to be set in the secondary/recoverable range. This acknowledges that an impact will occur, but that the manager feels recovery would still be possible from the impact (see Fig. 1.4).

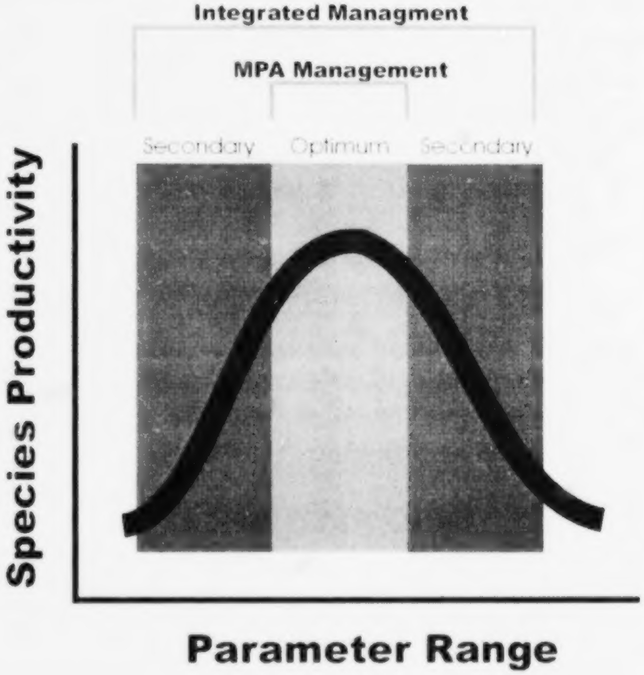


Fig. 1.4. Selection of parameter ranges for various management objectives.

The fourth step in the development of an MPA ecosystem framework is to identify the optimum ranges required for the assemblage of selected species in each ecozone. Optimum ranges are identified by taking the most sensitive, or narrow parameter values that fall from all the individual species profiles in each ecozone. For example, species X may have a narrow tolerance for dissolved oxygen so its optimum range for this parameter is used for the entire ecozone. The suspended sediment range for the same ecozone may be derived from the narrow requirements of species Y for this parameter. In this manner a complete suite of optimum habitat parameters are set for each ecozone. This exercise is completed for each season. The seasonal needs species assemblages in an ecotype define the range for each of the habitat parameters needed for a healthy, biodiverse, and productive ecozone.

The "community profiles" prepared for Habitat Management (see Appendix 1) for most of these ecotypes in the region will be useful in this step. It is likely that an ecozone in an MPA will be managed to keep the values for the physical, chemical and biological habitat parameters within the optimum ranges. Recoverable ranges could also be defined as you would in an integrated management framework. For an MPA, secondary ranges are not needed either for a definition of significant impact, or for compensation calculation frameworks, since an impact outside of the optimum range is not acceptable in an MPA due to its high level of protection.

All components of the ecosystem framework have now been identified through the four steps as outlined in Fig. 1.3. They are compiled into a document that the user can, knowing a specific location in the MPA for a proposed activity, look up the relevant ecozone and the habitat parameter boundaries that must be maintained to protect and conserve the MPA ecosystem.

With the relevant ecozone data in hand, managers or proponents can then ask and answer a series of questions, such as those in Table 1.2, to determine if the proposed activity will meet the ecosystem framework guidelines for the selected ecozone. Information may not exist to answer all questions posed, and in such a case, baseline studies will need to be conducted by DFO or a proponent prior to proceeding. The ecosystem framework can be used to justify the management decisions made by specifically identifying where risks are unacceptable or what additional information is needed before the process can proceed.

Table 1.2 Potential management questions used to apply the ecosystem framework.

1.	In what ecozone(s) will the proposed activity take place?
2.	What are the anticipated physical and chemical habitat parameters likely to be impacted in that ecozone by the activity?
3.	For those identified parameters that may be impacted, what are the anticipated to be the new physical, chemical, and biological parameter measures for the ecozone? Are these likely to be compounded by other existing or proposed activities (cumulative impacts)?
4.	Do the anticipated parameter values and cumulative impacts fall within the boundaries established for each of these assemblage of species within the ecozone?
5.	If boundaries identified in the ecosystem framework are to be exceeded, what risks and potential impacts of proceeding may be anticipated? Are they acceptable to the manager?
6.	If boundaries are not exceeded, or if risks and impacts are deemed acceptable the activity will proceed. What sort of monitoring, mitigation, etc. should be required to track actual impact of the proposed activity on each of the identified chemical and physical parameters?
7.	What evaluation and review of the activity will take place based on the actual physical, chemical, and biological parameter measures?

The ecosystem framework allows for varying levels of impact to be acceptable based on the ecozone targeted by the proposed activity, and species assemblage present in a particular season. For example, if an activity is proposed for a sensitive habitat of a key prey species, the physical, chemical, and biological habitat parameter boundaries necessary for attaining ecosystem objectives will be quite narrow. On the other hand,, if an activity is proposed for a non critical and non sensitive habitat that is not used significantly by any key species or life stage, then the parameter boundaries for that ecozone will be significantly broader, thus allowing managers to consider a wider range of activities.

Another approach is to use the ecosystem framework to provide flexibility and promote research in 'greening' activities. Proponents may demonstrate through scientific research that they can operate in a manner that produces less than previously anticipated impacts, and thereby potentially fall within the acceptable parameter boundaries set out by the ecosystem framework. In some settings this may allow managers to consider activities previously felt to be incompatible with a particular ecozone.

4.0 Framework Example

To complete an accurate example of how the framework will work using field data that exists for Musquash estuary would be a lengthy process requiring completion of a large portion of the framework itself. It is only intended to demonstrate how the framework could work. The indicator species used, the proposed activity cited, and the parameter boundaries applied may not be the same as in a fully completed ecosystem framework. Therefore, THIS EXAMPLE IS ONLY TO BE VIEWED FOR DEMONSTRATION AND MAY NOT BE ACCURATE IN ACTUAL CONTENT.

The Musquash MPA is relatively small, however, a number of ecotypes are identified though the framework development process. A proponent wants to build an in-filled walking trail across a portion of the low marsh. The following example shows how the ecosystem framework would function in determining how to proceed with the proposed activity. It should be noted that this example is "longhand" in order to demonstrate the whole process. Once established, managers need only consult parameter ranges identified in Step 4. The example follows the four steps as outlined in Fig. 1.3.

Example: Low marsh ecotype framework

STEP 1: Definition of the ecotype

The low marsh ecotype is a regularly flooded tidal salt marsh area, which is almost exclusively vegetated with *Spartina alterniflora*. Its flat grassy areas with meandering tidal creeks running through it, make it easily recognizable. It is behind the flow restriction at Five-Fathom Hole, which protects it from the full force of the oceans waves.

Physical properties of the low marsh ecotype
Water levels
Salinity
Temperature
Substrate composition
Substrate drainage
Nutrients – nitrogen and phosphorous
Sunlight

Oxygen
Noise
Physical impacts
Chemicals - Canadian Council of Ministers of the Environment

STEP 2: Select indicator and valued species

The low marsh has a limited number of plants and is almost a natural monoculture of *Spartina alterniflora* grasses. A few other plants that can be found in the low marsh include; sea lavender, glassworts, seaside aster, spike grass, *Gerardinia*, and *Spartina patens*. Both microscopic and macroalgae live on the sediments and attached to the higher plants. These include knotted wrack, rockweed, green and blue-green algae, and *Codium*.

There is an abundance of wildlife, common to the low marsh. The numbers of species is low but the abundance of those present is high. There are conspicuous seasonal changes in the marsh. In the winter ice-cover forms and is moved by the higher tides often ripping the grasses as it moves. In general there is little activity and the marsh is considered to be dormant.

Spring warming comes slowly as the cool ocean waters delays growth in relation to the adjacent land. The mud surface is the first to colour as it is warmed by the sun at low tide and algae begins to grow. In early summer the marsh turns green with grass and the algae colour fades robbed of light by the shading grass. The marsh is now at its height. The mud shows signs of feeding by swarms of crabs, snails, worms, and insects that make this their home. Swallows feed in the air and hawks hover looking for mice, which feed on the grasses at low tide. Snails, crabs, amphipods, mussels, and at high tide fish are present in large numbers. Wading birds are conspicuous feeders on the fish and invertebrates; rails, wrens, and red winged blackbirds are among the smaller birds. Canada geese feed on the leaves of *Spartina* and in the winter snow geese dig for rhizomes. Small mammals, mink, otters, muskrat and raccoons come into the low marsh to feed.

The following is a list of documented species in the ecotype. An asterix (*) marks those selected as key species for the ecosystem framework. This selection process would typically be done by a forum of scientists and community representatives.

Common Low Marsh Fauna and Flora for the Bay of Fundy

Flora
Algae
Ascophyllum nodosum
Focus vesiculosus
Enteromorpha
Ulva
Codium fragile
Diatoms
Blue-green algae (bacteria) - various species on the mud and *Spartina* stocks

Vascular Plants
Primary Plant Species

**Spartina alterniflora*, dominant species
Spartina patens found in patches mainly high marsh species

Secondary Plant Species
Plantago maritima
Triglochin maritima
Limomium nashii
Salicornia europaea
Salicornia bigelovii
Suaeda maritima
Atriplex patula
Glaux maritima

Fauna
Mollusca
**Littoria saxatilis* (rough periwinkle)
Modiolus demissus (ribbed mussel)
**Macoma balthica*
**Mytilus edulis* (blue mussel)

Crustacea
**Cancer maenas* (green crab)
Isopoda
Idotea phosphorea
Amphipoda
**Corophium volutator*
Corophium lacustre
**Gammarus mucronatus*
**Gammarus setosus*
**Gammarus tigrinus*
Ochestia grillus

Annelida
Neris diversicolor

Fish
**Fundulus heteroclitus* (mummichog)
**Gasterosteus* sp.

* Indicator species selected based on their role in the low marsh and covering all trophic levels

Trophic structure for selected species (all referenced Tables are presented in Appendix 1)

Primary producers
Spartina alterniflora (spring, summer and fall) (Table A1.7)
Diatoms (spring)
Blue-green algae (spring)

Primary consumers (all seasons)

- *Macoma balthica* (clam) (Table A1.10)
- *Corophium volutator* (Table A1.9)
- *Mytilus edulis* (Table A1.17)
- *Littorina saxatilis* (Table A1.14)

Secondary consumers (all seasons)

- *Cancer maenas* (crab) (Table A1.15)
- *Gammarus* spp. (amphipod) (Table A1.16)
- *Fundulus heteroclitus* (Table A1.13)
- *Gasterosteus* sp. (Table A1.11, A1.12)

Tertiary consumers

- Shorebirds
  - Herons (spring through fall)
- Mammals (all seasons)
  - Mice
  - Muskrat
  - Raccoons

STEP 3: Ecozone Habitat Parameter Definition

In a fully functional framework, each of these parameters would have specific numeric boundaries established for optimum productivity wherever possible. For this example, some parameters are presented as generally accepted descriptive ranges.

Water levels

Flooded by all diurnal tides under normal conditions.
Water levels up to 1.5 m on a mean high tide.

> To maintain the marsh there must not be any alteration to the flow. This is particularly true for the control at Five-Fathom Hole, which would change the depth width or quantity of tidal flow in either direction. Internal alteration of these flow conditions will affect the marsh by reducing flows and possibly increasing velocity and changing patterns of the currents on the seaward side.

Salinity

Estuarine salinity levels for best *Spartina* plant growth 20 to 33 ppt spring through fall. Winter levels can be allowed wider range but fresher causes more ice and related damage and saltier can result in damage to *Spartina* rhizomes.

Water Temperature – see Appendix 1 for background values. Temperature should not change more than 10% from background by human activity. All seasons.

Substrate composition - see Table A1.5 in Appendix 1

No activity which would change the composition of the sediments including dumping or un-natural siltation levels from the surrounding areas. Natural silt input is required to maintain the level of the marsh against rising sea level but no additional silt should be allowed since it will result in the area becoming high marsh. Fine silts will plug the pores in the substrate reducing drainage at low tide possible suffocating *Spartina*. All seasons.

Substrate drainage

When the tide goes out water from the substrate drains into the tidal creeks. This is very important because it allows oxygen levels to increase in the substrate thereby allowing nitrogen fixing bacteria to flourish and *Spartina* roots to breathe. It is this drainage along the creeks which is thought to be the reason for the taller marsh grasses in these areas. The shape of the creeks and the compaction of the substrate should not be changed. All seasons.

Sedimentation

Natural erosion rates on land add about 3mm of sediment to the marsh each year. This has been enough to keep up with the rate of sea level rise to this day. Sedimentation and erosion rates from anthropogenic sources should be kept to zero. All seasons.

Nutrients

Biologically available nitrogen is the limiting factor for primary production in this ecozone. Studies in the New England States indicate that phosphorous is a close second as a limiting nutrient. No additional nitrogen or phosphorous from human activities. All seasons.

Sunlight

The marsh needs full sunlight for algal production (spring) and the *Spartina* growth (spring through fall). In the spring, *Spartina* shades out most of the algae.

Oxygen

Oxygen levels in the water are not naturally limiting to the aquatic environment and should be kept at maximum saturation in tidal waters.

Oxygen is limiting for *Spartina* root growth. The plants move oxygen to the roots through hollow cores but additional levels are needed for optimum growth as noted in the substrate drainage section. Full oxygen saturation of the water. All seasons.

Physical Biological

Spartina forms a physical habitat in this ecozone. *Spartina* is frequently divided into two forms tall and short. The tall form occurs along the banks of the tidal creeks and on accreting areas within the marsh. At this site it generally reaches 1.25 to 2 m in height. The stems are thick and widely spaced. The short form grows on the remaining area. These plants may be as short as 10 cm, have thinner stems, and grow more densely packed. In less suitable areas they may be very thin and widely spaced. The tall form creates the best habitat for aquatic species to use on the flood tide because the spacing allows for passage while still providing cover. Algae on the surface of the substrate and on the lower parts of the plants in areas where they are widely spaced, are often enough to colour the area green. This provides a food source for many primary consumers.

Physical

Spartina has many adaptations to survive in the high salinity and low oxygen substrates. Physical impact to the stalks can break the salt resistant outer coating and /or the air supply to the roots. Physical impact by human activities must be kept to an absolute minimum, and preferably zero tolerance.

The tidal channels will be dealt with separately but it is important that no activity restricts or redirects water flow because the substrate and form of the channels are in a delicate balance with the tidal exchange and currents.

Noise

Most of the birds and mammals that use the marsh are disturbed by the noise of human activities. Noise levels should be kept below the level and types of noise that elicits a defensive or escape reaction for all animal life. Exceptions will be allowed in the fall for bird hunting.

Chemicals

The levels set in the Canadian Council of Ministers of the Environment (CCME) water quality guidelines for marine aquatic life are to be considered the maximum level of pollution allowed. The target is to reduce these levels to the lowest possible for naturally occurring contaminants and to zero for man made contaminants.

Heavy metals

Low marshes are a sink for heavy metals, which in the anoxic substrates are not biologically available. They do, however, make their way into the plant materials and food chain in low levels and the direct human inputs to the marsh should be zero tolerance and other inputs should be minimal. All seasons.

STEP 4: Final Evaluation of Proposed Activity

Example: A proponent proposes to build an in-filled walking trial across a portion of the low marsh to a major tidal creek and then along the top edge of it to the high marsh. The trail is to provide access for bird watchers and field naturalists during the spring and summer and for duck hunters in the fall.

Environmental impacts assessment

An in-filled walking trail would:

- restrict tidal flow to low and high marsh above it
- require some drainage culverts which would restrict flow of tidal waters past the trail and reduce sediment deposition rates
- restrict access of aquatic species to marsh feeding areas
- bury marsh, directly destroying "X" area of *Spartina* type habitat
- compact substrate under the trail, impacting on low tide drainage, temperature and oxygen levels in the substrate
- provide access to off trail areas of the marsh which could be trampled by hunters and others causing breakage of the *Spartina*.
- increase human disturbance and noise for nesting and feeding areas for wildlife.

Comparing these to the ecozone framework rules the proposed trail clearly exceeds several of the ecozone parameters identified for the low marsh.

5.0 Framework Development Tasks and Strategy

The development of a Musquash Ecosystem Management Framework document that can be used to guide and defend management decision-making will require collection and review of a wide array of existing information. The information will need to be evaluated and categorized, and ultimately, selections from the categorizations must be made to incorporate into the framework. Gaps will exist in the available information; however, it is unlikely that these gaps will prevent user implementation of the framework. Instead, gaps are likely to show where more work will need to be done to fill the framework in its entirety. This can be done through various mechanisms such as research, monitoring, user monitoring, data collection, etc.

To make the Marine Protected Area operational, a robust ecosystem framework has to be developed and set at the core of the management process. This has seldom been attempted for an MPA but similar frameworks have been developed for environmental review and monitoring and the basic principles and techniques can be brought together for this framework. The US Fish & Wildlife Service has developed Habitat Evaluation Procedures (HEP) in support of their habitat policies and environmental review. The Ecological Monitoring and Assessment Network (EMAN) and DFO's coastal biologists have further developed monitoring protocols for coastal ecosystems. These approaches combined with the theoretical ecosystem based management approach taken by the Australians in the Great Barrier Reef MPA, and DFO's large oceans management areas gives us a good foundation. The basic ecosystem framework has been outlined for the Eastern Scotian Shelf Integrated Management (ESSIM) area, and fleshed out for the ecotypes of the Banquereau area of the Gully MPA in previous work for the Oceans & Coastal Management Division. Modifications to previous eco-typing approaches will be used in this application to make it more applicable to the coastal area.

There appears to be ample data and background to give a good basic framework for Musquash, however, there are several chemical contaminants that do not have suitable information at the individual species level to use reliably. In these cases we will adopt the CCME guidelines for marine aquatic life to supplement the framework and consider values set for other temperate areas, particularly the New England area.

Further consideration will have to be given to maintaining population levels of species to ensure adequate food sources for predators, and enough predators to keep forage species from getting out of balance. Since there is some harvesting allowed in the MPA, setting these levels will be important as will setting of levels to maintain a full range of age classes and biodiversity. This will likely be an area for further research and modeling. If information is available on the population levels and densities needed to support the food web it can be included.

The following tasks will be necessary to complete an Ecosystem Management Framework for the Musquash MPA.

Table 1.3. Framework development task list for Musquash Ecosystem Framework.

Task	Activity	Description
1	Collect and Review	Collection of all existing and relevant literature, scientific studies, management papers, and additional materials.
2	Ecotype Preparation	Based on various existing ecotyping methods, select / modify one for Musquash.
3	Identify Ecotypes	Apply ecotyping methodology to Musquash to define and map relevant ecotypes for the project area.
4	Species Information	Create a species list by season and trophic level, and identify the relevant ecotypes used by each species at each life stage.
5	Species Selection	Select key / foundation species to be used in the framework based on scientific relevance, and input from stakeholders. Confirm that the species selected are easily related to identified ecotypes.
6	Species Parameter Boundaries	For each key / foundation species identified for use, prepare a comprehensive list of the physical, chemical, and biological habitat parameter ranges. Where feasible this should be numeric and based on scientific literature.
7	Assemblage Parameter Boundaries	Set parameter boundaries for the assemblage of species found in each ecozone by season
8	Existing Parameter Measures	Compare existing habitat parameter measures for Musquash Estuary with those ranges identified above. Ensure that they support one another. Identify gaps in information on various parameters for Musquash.
9	Gap Analysis	Identify and analyze gaps in existing information from previous tasks and determine significance for implementation of the ecosystem framework
10	Develop a comprehensive reference document	Compile a step by step document of all previous steps and findings to demonstrate the background work that supports the final Musquash Ecosystem Framework document. These steps will become the appendices to the final user document.
11	Develop Musquash Ecosystem Framework Document	Compile a reference document for managers that outlines appropriate questions to ask proponents, how to select parameter boundaries for specific activities, and options for consideration in the decision making process. The Framework document will also provide all current ecosystem material that needs to be referenced in the decision making process.

The final product will provide an appendix of all the levels developed for the individual species as background. These as well as the ecozone parameters will be in narrative form and numerical form when ever possible.

6.0 Next Steps for Musquash Framework Development

There are several tasks necessary to complete a Musquash Ecosystem Framework (Table 1.3). Although some of the steps might be carried out concurrently, completing them in sequence is more effective in producing a high quality framework. Similarly, the work could logically be broken into a few phases, however, completing a polished final product at the end of several phases would not be an efficient use of time given that much of the information will be compiled in a raw data form.

In order to meet budget expectations, DFO should select one of two following options for developing the framework. In both instances a complete ecotyping activity would occur, along with completion of steps 1-4 in Table 1.3. The following two options are considered feasible.

- Option 1: Complete species profiles for all species in all ecotypes based only on easily attainable species profiles. This option would produce a full framework with minimal detail regarding optimal chemical and physical habitat parameter ranges, but would highlight all gaps necessary to complete the framework, and provide a framework that would be somewhat functional to all ecotypes.
- Option 2: Complete rigorous species profiles for all species in only one or two ecotypes to show how completely functional the framework could be with a high level of effort in data compilation. This approach would involve seeking out any and all relevant research regarding the optimal physical and chemical parameter ranges for the selected key species in the one or two demonstration ecotypes. This approach would demonstrate what is achievable in a fully researched framework, but would lack complete functionality until all ecotypes were completed.

For both of these options it was expected that DFO and the Musquash Advisory Committee (formerly the Planning Group) would carry out an exercise to address Step 5, the identification of key / foundation species for incorporation into the ecosystem framework by involving scientists and community members.

Acknowledgements

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References

[1] Fisheries an Oceans Canada. 2002. *Musquash Estuary: A review of management requirements (June 2002)*. Oceans and Coastal Management Division, Maritimes Region. Unpublished. 42 pp.

[2] Canadian Council of Ministers of the Environment. 1999. *Canadian water quality guidelines for the protection of aquatic life*. In: Canadian environmental quality guidelines, 1999. Winnipeg, Manitoba.

[3] Thomas, M.L.H. 1983. Salt Marsh Systems. Pages 107-118. In Marine and Coastal Systems of the Quoddy Region, New Brunswick. M.L.H. Thomas (Ed.). Canadian Special Publication of Fisheries and Aquatic Sciences 64: 306 pp.

[4] East Coast Aquatics. 2003. *An Ecosystem Based Framework for Oceans and Coastal Management. 2nd Draft*. Fisheries and Oceans Canada. Bedford Institute of Oceanography. Bedford, Nova Scotia. Unpublished. 14 pp.

CHAPTER 2

Steps in the Development of Musquash Ecosystem Framework

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Introduction

The overall objective of the management plan for the Musquash Marine Protected Area is to limit or avoid disturbance, damage or destruction due to the direct influence of human activities. The development of a Management Plan for the Musquash MPA is being approached through the development of an ecosystem framework. This Chapter completes tasks 1-8 of the development of an Ecosystem Framework, as outlined in Chapter 1 (Table 1.3). The development of an ecosystem framework for the Musquash MPA requires a series of steps: (1) definition of the ecotypes, (2) identification of biological components of the ecotypes, (3) selection of key indicator species, (4) specification of the individual physical, chemical, and biological habitat parameter boundaries, and (5) identification of the optimum (physical, chemical, and biological) ranges required in each ecotype for the assemblage of selected species.

Hence, Chapter 2 provides information on the following:

1. Demarcation and identification of all the possible ecotypes available within the MPA, using *MapInfo Professional 5.5*. Map these ecotypes and indicate those that are confirmed and those that are inferred.
2. Lists the species (confirmed and expected) within each ecotype.
3. The number of species using schematic trees of species by ecotype and trophic group (refer to Tables in Appendix 2).
4. Species life history requirements of selected species and any information on their sensitivity to disturbance.
5. Proceedings from a workshop of experts who assisted in narrowing the number of species from the schematic tree to use in monitoring.

1.0 Ecotypes

There are eight ecotypes identified from the literature and from maps (see [1]) in the proposed MPA. The details on the sizes (determined from MapInfo mapping) of the various ecotypes identified are listed in Table 2.1. Fig. 2.1 and 2.2 show typical species zonation patterns on a rocky intertidal ecotype and on the salt marsh ecotype. The advantages and disadvantages of using different parameters for monitoring the Musquash salt marsh and adjacent areas in the MPA are presented in Table 2.2.

Table 2.1. Details on the sizes (determined from MapInfo) of the various ecotypes identified. Details on the distribution of some ecotypes were not available and hence the values are indicated as being 'not available'.

Ecotype	**Polygons**	**Area (in m^2)**
Rocky Intertidal (includes boulder beaches)	30	969,976
Tidal Pools on rocky substratum	Not available	Not available
Sand & Gravel Intertidal (includes pebble-cobble beaches)	15	230,677
Mudflat Intertidal (includes mud-sand/cobble beaches)	9	3,434,718
Salt marsh	18	4,369,639
Pannes within salt marsh	Not available	Not available
Subtidal mud and sand	Not available	Not available
Subtidal rocky (hard bottom)	Not available	Not available

The following sketch shows the typical zonation pattern on the rocky intertidal areas in Musquash Estuary [1]. The species typically found in each of the zones are indicated in the species list for the rocky intertidal ecotype (Appendix 2, Table A2.1)

Sub-maritime fringe	Terrestrial: Trees, grasses and other flowering plants Edge of turf: Few flowering plants below this point
Supralittoral Zone	Upper limit of lichens: *Verrucaria, Xanthoria, Caloplaca, Parmelia* Upper limit of *Littorina*
Supralittoral fringe	Upper limit of Barnacles; Narrow band of *Fucus spiralis*
Midlittoral Zone	Under *A. nodosum* canopy: *Sertularia, Flustrellidra, Fabricia.* May be present: *Arcosphoina arcta, Mastocarpus stellata, Chondrus crispus, Palmaria, Colissella (Acmaea)* Upper limit of *Ascophyllum*; Present: *A. arcta, M. stellata, C. crispus*
Infralittoral fringe	Lowest low water; *Strongylocentrotus, Alaria, Laminaria*
Subtidal Zone	

Fig. 2.1. Typical zonation in the Musquash rocky intertidal ecotype [2].

The following sketch shows the typical zonation pattern on the salt marsh areas in Musquash Estuary. The species typically found in each of the zones are indicated in the species list for the salt marsh ecotype.

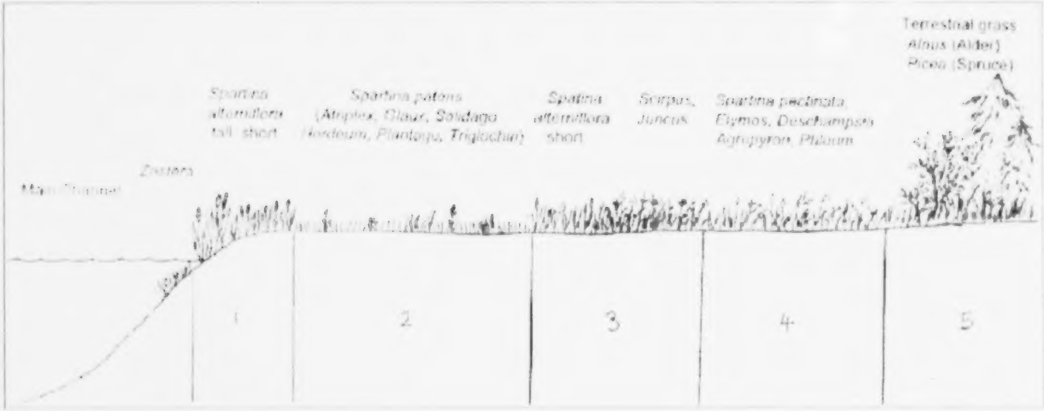

Terrestrial grass
Alnus (Alder)
Picea (Spruce)
Spartina alterniflora tall short
Spartina patens (Atriplex, Glaux, Solidago Hordeum, Plantago, Triglochin)
Spatina alterniflora short
Scirpus, Juncus
Spartina pectinata, Elymos, Deschampsia Agropyron, Phleum
Zostera
Main Channel
1
2
3
4
5

Fig. 2.2. Typical zonation in the Musquash salt marsh ecotype [2].

2.0 Species

Tables A2.1 to A2.8 in Appendix 2 list the species recorded in each ecotype. The tables also provide information on the common names (wherever possible), the trophic level of each species and whether the species is confirmed or inferred as occurring in the ecotype. Where possible the precise zone of occurrence of the species is indicated. Fig. 2.3 to 2.7 are based on maps and previous studies (summarized in [1]) and show the distribution of each ecotype within the estuary.

Table A2.9 in Appendix 2 list all the birds that were observed in the Musquash MPA while Table A2.10 (also in Appendix 2) summarizes the number of rare, very rare and vagrant species of birds reported by at various locations. Tables A2.11 to A2.21 (Appendix 2) provides details on the bird species observed at various locations around the Musquash MPA while Fig. 2.8 shows the locations from which birds were observed. Table A2.22 in Appendix 2 lists the plankton recorded in the estuary.

Table 2.2. Advantages and disadvantages of using different parameters for monitoring the Musquash salt marsh and adjacent areas in the MPA. Modified from [3].

Advantages	Disadvantages
Tidal Hydrology	
Easy to take reading Low level of effort Tidal restriction is easily observed and recorded	Time-consuming because reading must be taken over tidal cycle
Salinity	
Relatively easy to take reading Samples from pore water and surface water Important chemical parameter	Samples should be taken at multiple sites Equipment must be calibrated Affected by rainfall, hydro-dam discharge and seasonality
Plants	
One or two surveys per season Plants are relatively easy to identify Plants integrate wide array of stressors such as salinity, hydrology, and substrate conditions	Mobility on marsh surface may be difficult Late/early season identification can be difficult Difficult to isolate specific stressor
Invertebrates	
Wide range of organisms covering all trophic levels Large number of organism per sampling effort Organisms complete their life cycle within the marsh, and reflect ambient and past habitat conditions Well documented biology and ecology	Sampling can be challenging in mud substrates Sorting organisms from debris is time consuming Identification of some taxa (especially polychaete worms) is difficult Equipment cost are fairly expensive
Fish	
Fish represent a higher trophic level than plant or invertebrates Composition of marsh residents may reflect environmental conditions Salt marsh fishes are generally easy to identify	Many samples (over several years) are often need to accurately evaluate a fish population or community Mobility of fish presents unique collection challenges Manpower (3 people minimum) Equipment cost (i.e. bag seines)
Birds	
Birds are popular with both the public and scientist and a large pool of potential data collectors exists The life history, ecology, and geographic distribution of birds is very well known Easy and inexpensive to survey due to their visibility Birds can indicate the integrity of landscapes since they can easily move from one site to another Birds are sensitive to habitat conditions and disturbance by noise, human visitation, and predatory animals (cats, dogs, racoons, etc.)	Birds present at a site will vary daily, seasonally, and randomly, and several visits are required to get accurate and representative data Marshes and adjacent areas are important for migration, feeding, or breeding, so surveys should be scheduled to capture all uses Most bird identification is done by sound so surveyors need to be proficient with bird calls

3.0 Schematic Trees of Species by Ecotype

There are several species in each trophic level in each of the ecotypes identified in Appendix 2. The schematic trees presented in Appendix 3 (Figs. A.3.1-A3.7) provide visual summaries of this information for each of the ecotypes. This information may be used in the identification of key species from different trophic levels from each of the 7 identified ecotypes within the Musquash MPA.

4.0 The Species Life Requirements of Selected Species

Appendix 3 provides the details of the species life requirements of selected species. Information on individual species were researched from the literature and collated into life history tables. Table A3.1 lists the species from each ecotype for which life history characteristics have been collated. Information is presented on: six algae, two grasses, one sponge, one anemone, three worms, three gastropods, four bivalves, one barnacle, one crab, two amphipods, one lobster, one tunicate; 14 fishes, four birds and one mammal. See Appendix 3, Table A3.2 for details.

5.0 Ecological Indicators and Monitoring from the Literature

The marsh, mudflat and rocky intertidal environments can be dynamic with very large changes in the physical variables. Some suitable species for detecting disturbance in such environments are noted in the information obtained from the literature and these are present below. Some of the possible methods for detecting environmental changes from the literature are also presented below:

From [5]:

Indicator species: Rocky Intertidal:

The strong dominance of *Ascophyllum nodosum* in this ecotype reduces the utility of other species as indicators of change. *A. nodosum* appears to be relatively resistant to oil pollution and probably protects underlying biota. It is frequently found well into polluted estuaries, provided that the salinity does not fall to low levels. Thus the mid-shore zone in the rocky intertidal ecotype may have unusual resistance to pollution.

In the upper rocky intertidal tidal zone, *Fucus spiralis* is universally present and is quite susceptible to oil pollution [17, 18], and also to the effects of detergents [19]. It may well be a very good indicator species.

In terms of fauna in rocky intertidal ecotype, the sedentary species would offer the most hope as indicator species. These would include the common species such as the blue mussel, *Mytilus edulis* and the northern rock barnacle, *Semibalanus balanoides*. However, Thomas [5] reported that these two species are not very sensitive to pollution.

From [5]:

Salt marsh description:

Salt marshes consist of extensive flats at a level from about mean high water to extreme high water, dissected by a network of channels. The channel systems in the Musquash marshes are relatively simple. Along the upper channel banks and edges the flora is usually dominated by the salt marsh cord grass, *Spartina alterniflora*. The only other plants present are various algae, mostly of very small size. From the channel edges the level of land rises very slowly. On these salt-marsh flats, the flora varies considerably with minor changes in level. In the upper part of Musquash, these flats have slightly raised areas dominated in summer by the annual herb, *Salicornia europea* (marsh samphire or goose tongue greens). Associated with this species are *Limonium nashi*, sea lavender, and *Plantago maritima*, both in small quantities. In winter these areas are devoid of macro-flora and dominated by microscopic algae. Slightly lower ground surrounding these areas are carpeted by an almost monospecific growth of *Spartina alterniflora*. In these locations this grass differs from the same species found along channel edges in that it is much shorter.

In the lower portions of the Musquash system, *Salicornia* dominated areas are comparatively rare and the flats are dominated by continuous growths of *Spartina alterniflora*, salt marsh cord grass. *Spartina patens* is typical of areas lying slightly higher than where *S. alterniflora* occurs. In many areas, however, *S. patens* lies closer to the channels than *S. alterniflora*. This situation may arise either because man-made dykes have prevented normal sediment deposition, or because natural sediments settle out rapidly close to the source, namely the channels. Where *Salicornia* dominated flats occur, *S. patens* dominated areas occur landward as the level rises slightly away from the channels.

Either *S. alterniflora* or *S. patens* dominate the majority of the salt marsh surface. In these '*Spartina* meadows' there are relatively few associated species. *Limonium nashi*, sea lavender is usually present in small numbers and on landward fringes. Where freshwater seepage occurs, rushes or reeds (*Scripus* sp. or *Juncus* sp.) may be present. Moving further inland, wet areas are frequently dominated by *Scripus* sp. or *Juncus* sp. with many other species being present. On dryer areas and generally around the landward rim of the salt marshes *Spartina pectinata*, slough grass is usually dominant.

Fauna of Salt Marsh

Salt marshes in the Musquash system have few resident fauna. Few marine species are present. Few *Littorina saxatilis* occur in the more seaward portions and *Mytilus edulis* may occur in creeks if there are suitable hard substrates for attachment. In creek sediments, the bivalve mollusc, *Macoma balthica*, is often dominant and the worm, *Hediste (Nereis) diversicolor* is sometimes found. Other fauna consist of terrestrial invaders at low tide and marine invaders at high tide.

The salt marshes are very important feeding and resting areas for many birds and mammals such as raccoons, moose, white-tailed deer, Canada geese, black duck, and many other migratory species. As a result, any damage to salt marshes can have serious consequences for these species.

From: [20], [21]

Capitella capitata is known from a variety of habitats and is a good indicator species of pollution and unpredictable shallow water environments. It is tolerant to pollution and low oxygen and is able to exploit local concentrations of organic matter. It has a variable life history and adults can produce as few as 2 eggs to as many as 600. One or several broods can be produced and time to maturity is about 30-60 days. Settlement of larvae occurs in both winter and summer with the greatest settlement occurring from May to October. Sexes are separate with males readily distinguished by large copulatory setae on the eight and ninth setigers. The species has been collected from waters with salinities from 0.3‰ to 36‰.

The scaleworm, *Lepidonotus squamatus*, is an important fish food and can be abundant in rocky areas.

From [22]:
The characteristics of benthic tidal flat communities result from the interaction of the physical and the biological environment. Human activity, however, may influence the tidal flat environment and, therefore, play a role in the development of some of these communities [23], [24]. Human activities include sewage, drainage from dump sites, and run-off. Statistical analyses used to determine if disturbance has occurred included the (a) Shannon-Weiner diversity index (*H'*) calculated for each sample site and for each transect – the higher the value of *H'* the more diverse the sample; and (b) Evenness (*E*) based on the Shannon-Weiner index value – values range from 0 to 1, with a value of 1 indicating equal abundance of species. *Harmothoe imbricata* found in the mid-littoral zone, *Eteone longa* found in the intertidal and subtidal mud, and sand areas, and *Capitella capitata* found in intertidal mud and sand, are all known as disturbance tolerant species. Samuelson [22] proposed a four part zonation of polychaete communities with increasing distance from human caused disturbances. The four zones are: (1) a heavily disturbed zone, closest to the disturbances and devoid of polychaetes, (2) a disturbed zone, characterized by increased densities of a few opportunistic species, (3) a moderately disturbed zone, characterized by increased species diversity in relation to the fourth zone, and (4) a relatively undisturbed zone, furthest from the sources of disturbance and characterized by moderate species diversity in comparison to the other three zones.

From [25]:
In a Cape Cod Bay salt marsh, most of the mummichog, *Fundulus heteroclitus*, migrated upstream in the fall indicating that most of the fish remained within the salt marsh throughout the winter. High numbers of individuals were recorded in upstream salt marsh pools in the fall and winter. They burrowed into the sediments of upstream pools in the winter, probably seeking refuge from extreme nighttime temperatures. *F. heteroclitus* can survive temperatures down to −1.5 °C. The sediments characteristics of in individual pools may affect over-wintering habitat selection by influencing temperature since pools with darker coloration organic surface layers may be more effective at retaining heat and would be more fine grained due to the organic matter.

From [26]:
Many approaches to benthic community assessment depend on accurate species identification. These assessments include multi-metric benthic indices such as species richness (numbers of species) or diversity. Traditional methods such as Abundance Biomass Comparisons (ABC) method [27] and diversity indices [28] also depend on accurate species identification.

From [29]:
Ecological assessments and monitoring programs often rely on indicators to evaluate environmental conditions. An ecological indicator is any expression of the environment that provides quantitative information on ecological resources; it is frequently based on discrete pieces of information that reflect the status of large systems [30]. These include the condition of resources, magnitude of stresses, exposure of biological components to stress, or changes in resource condition. Because the act of selecting and measuring indicators involves a human cognitive and cultural action of observing the environment in a particular way under certain premises and preferences, indicator information implicitly reflects the values of those who develop and select them. Ecological indicators are most often developed by scientists, expressed in technical language, and target aspects of the environment that scientists consider useful for understanding ecological conditions. Yet, setting environmental policy priorities and making environmental decisions involves considering public values for ecosystems.

General Comments

While there are a number of species in each ecotype, the experts initially consulted were unaware of specific species that may be useful in indicating environmental change. The mummichog is a very "hardy" species and can withstand certain changes in its physical environment. It may not be a suitable species to indicate salinity and temperature changes at the population level.

6.0 Summary of Workshop on Selection of Indicator Species

The aim of this workshop was to determine a suite of potential indicators of health and of change in each of the ecotypes described. Experts were invited to participate; those who could not attend were encouraged to submit their suggestions via email. A list of the participants can be found in Appendix 4. The workshop was held on November 3, 2004 at the Canadian Coast Guard Building in Saint John, New Brunswick.

The workshop started with a presentation by Maria-Ines Buzeta on the chronological development of Musquash Estuary into an Area of Interest and the steps being undertaken to designate it as a Marine Protected Area. Rabindra Singh presented background information on the Musquash ecosystem and the objectives of the workshop. A presentation by Art MacKay explained how indicators were selected for the St. Croix Estuary, how those indicators are being monitored, and how the information obtained is being used. This was followed by extensive discussions on the purpose of the workshop and the method of selection of indicator species. Some notes on the extensive discussions follow.

The St. Croix Estuary Example

The St. Croix Estuary monitoring was done not by selecting species but by looking at species re-colonization (i.e. *Nereis*, *Cragnon*). Juvenile *Mysis* and flounder disappeared when environmental conditions were poor but found their way into the estuary as conditions improved. Generally, when conditions got better there were greater diversity and abundances of species. Conversely, when environmental conditions got worse there were fewer species and numbers. When presenting data it is imperative to know who the audience (public or scientists) is, so data presentation can be geared specifically to them. The slides presented to the workshop participants were intended for the public, and the colors in the slides represented real data from transects. Comparing the 1970s data to 2001 and 2003 data revealed the same general trend, with a continued drop in biodiversity as one went up river.

ACAP – St. Croix has made good use of volunteers to conduct annual monitoring (one week each year) that includes transects. In the case of Musquash MPA, maintaining the community links would be important because there are people who are concerned about their environment and they would make good volunteers. In addition, local towns, cities and industries may be willing to possibly contribute in some way. In the St. Croix, several chemical analyses are done by trained volunteers including pH, ammonia, salinity and temperature. Samples are also taken of sediment, redox and sulphide measurements according to the NB's Department of Agriculture, Fisheries and Aquaculture (DAFA) criteria. Data are also collected on coliform and pollution sources. ACAP- Saint John also does monitoring using trained volunteers, who performed a series of chemical analyses: pH, phosphates, oxygen, turbidity and salinity. They have also collected faecal coliform samples which are analysed in labs at New Brunswick Community College, Saint John.

Sediments can have a history of storms and contaminants. Elevated levels of copper and arsenic from streams are an example; hence, certain metals can be entering the ecosystem from natural stream sources. Environment Canada has extensive data on naturally occurring metals found in stream outflows. Monitoring the cumulative effects in sediments over time for contaminants and seasonality is also important. From the example of the St. Croix Estuary program, monitoring the appearance and disappearance of species would be a useful index. The use of a small inexpensive remote video camera to assist in monitoring was found to be very practical in the St. Croix Estuary. The video is used to determine whether anything has changed. This is followed by "triage" (ranking in terms of importance or priority) if there is a hot spot. A red flag may not lead to the science behind it but will lead to further study and decisions.

Why we need to monitor

There is a need to identify the purposes of any monitoring programs. The whole aim of the monitoring program for Musquash would be to answer the question "How are we doing?" We need to be able to get a handle on how much change is occurring and how much is too much. Some changes may be positive if certain activities that have been occurring are restricted. Hence, monitoring is done to detect changes and to determine effects of a known stressor. Change is detected first and then a determination is made on whether the cause is local or global. Alternatively, rather than using a few indicator species, a general survey can capture the trends in numbers and biodiversity. If change has occurred it will raise a red flag and then a major survey is done, but we do not want to wait until irreversible ecosystem changes occur before taking action. Once the change has happened, we need to find the cause, magnitude and rate of change. We also need to determine what is an acceptable vs. unacceptable rate of change.

The purpose of monitoring will be to record change; we do not have to know the science behind the change, but detecting it can trigger a red flag to do more detailed studies. We need to know if the changes in the marsh are from natural causes or from human actions. The challenge will be designing a generic survey or choosing an indicator species that will capture or detect this change. If change is detected we need to know what steps must be taken to avert further change.

The assumption is that Musquash is a healthy environment and monitoring would be used to detect change. In developing a Musquash monitoring program, we can begin at the community level and measure only the things more highly valued, and those variables that will tell us what is happening (i.e. if trout are being lost, monitor to determine the causes). If we want to monitor community structure, this requires intensive sampling and requires expertise. Monitoring how things have changed over time can be done by monitoring species abundance and changes in diversity. Statistical tests are available to test diversity changes species lists can be useful for statistical analysis based on taxonomic relatedness for changes over time. This method does not rely on sample size and the presence of species changes with stress in a very predictable way. Crustaceans and amphipods are generally sensitive to changes and have been recorded as being the first group of species that move away (or disappear) from aquaculture sites and may be good organic enrichment indicators. In soft sediments, the appearance of large numbers of *Capitella* can also be a good indication of organic enrichment.

In some situations, community studies can be used to detect changes if we are looking at species changes including soft bottom invertebrates. At the community level, however, changes in fish populations may be more noticeable by members of the fishing community. Less is known about changes related to fish communities. For example, the CAMP (Community Aquatic Monitoring Program) works with community environmental groups to sample fish communities onshore every month between May and September. The idea being tested is that the health of estuaries may be reflected in the types of fish and crustaceans found there and their relative numbers. It involves beach seining and is a community-based program to monitor what is there, the seasonality, and the scale. In 2004 as part of CAMP, community groups sampled 10 estuaries in NB, 3 estuaries in PEI and 3 estuaries in NS in 2004 and a number of universities and other partners sampled additional sites.

The use of biological indicators may not be the best option for monitoring whether a system is balanced or healthy because the loss of a species cannot always be used to tell that a system is stressed. In addition, using several different species to cover all the variables involved is not economically viable. So there is need for something that shows that the ecosystem is not balanced before species are lost. There is need for a mid-level indicator between the species level and the population level. In such a setting stress can be measured by behavioural changes in species. This balances both the temporal and spatial scales. Capturing the natural variability in species is very difficult and probably too costly. In such situations, monitoring processes (e.g. reproduction and growth) might be best. For a natural area, we really should be looking at processes, not species.

The establishment of Musquash as an MPA would help us monitor climate change impacts, as sea level rise and even global warming are possible stressors in salt water marshes. The MPA could serve as a reference to global change, whatever the change may be, once a baseline has been established. The Musquash monitoring program could be used to detect changes as well as spatial and temporal variability. For this, we should list potential stressors, develop a cumulative effects framework, and understand the baseline variability. One way to approach the monitoring would be to get data on abundance and species sampling along with temperature, salinity, oxygen, organic input, and cover of macrophytes, for example, then look at the correlations between these variables.

The need for a baseline

For Musquash MPA we need to know the starting points and the factors that could have potential negative impacts on ecosystem health. Once this is known the monitoring program could be designed. Baseline information is needed to be able to detect changes from the natural ecosystem variation. Then if there are changes due to unknown events, these would be detected and further monitoring would be devised. It is also necessary to know whether there will be regulations imposed to show change and whether there will be any monitoring of the lobster, scallop and clam fisheries. Such a baseline study would also record information on the geology of the area, and watershed extent and influence.

The best indicator species may be ones that have not been thought of or mentioned, hence, a suggestion was put forward that a detailed and comprehensive survey be done to get the baseline data on each ecotype in Musquash, and then use that data to design a monitoring program. For each of the ecotypes, the baseline information needed, and the stressors and activities must be identified. From that the monitoring framework can be developed. We need to know what the starting point is; otherwise we would not know if there has been a negative effect caused by human activities. This information would be used in the determination of biological indicators and quantity, the establishment of water quality indicators and of reference values.

For the baseline study, intensive surveys could be done within a short time-frame. Any previous surveys found in the literature could also be redone. Sampling intensely every ten years should be able to detect changes but would not answer the question about what are the causes. Superimposed on the snapshot of every five to ten years, would be other studies specific to these other issues.

Potential indicators

In selecting biological indicators, managers concerned about losing species may find it helpful to use the Valued Ecosystem Components (VECs). For example, if it is fish, a survey is designed to detect changes in fish abundances/species. If it is habitat or contaminants, then the surveys would be different. The premise is to protect marine habitat such as bird areas or marshes, so the sampling should reflect this.

The baseline survey would indicate the presence/absence of the various species currently in Musquash. Low abundance of *Zostera* may indicate eutrophication. Most of the invertebrates in the salt marsh are not particularly useful as indicators. *Nereis* likes low salinity but is not necessarily a good indicator of salinity changes. Migratory species are not as useful because their number depend on other habitats outside of the monitoring area. In selecting indicators, the size of the indicators maybe important, for example, herpacticoid copepods which feed on diatoms would be good indicators of diatom changes. Monitoring *Spartina* might result in the highest benefit because it will be linked to any changes in food supplies to invertebrates.

In addition to species, monitoring human activities (that is, the human-use ecological footprint) such as ATV uses on the marsh, fishing, and sweetgrass harvesting can be a surrogate for monitoring *Spartina* habitat.

Indicator species for the salt marsh (Key species, habitat builders, modifiers)
Spartina is officially recognized as a keystone habitat builder in Europe because without it there is no marsh. *Limonium nashi* (sea lavender) and *Plantago maritima* (seaside plantain/goose tongue) should also be monitored because they can be targets for harvesting by the public. *Hierochloe* (sweetgrass) is susceptible to changes in immersion regime and hence may be a good indicator of sea level rise. It is also susceptible to high salinity (needs freshwater) and hence can indicate changes in the salinity regime, e.g. increase in freshwater flow from the dam.

Indicator species for panne: Sampling in marsh pannes has recorded sticklebacks, mummichogs and eels. Mummichogs are most robust species so they are not particularly useful if looking at presence/absence but could look at developmental abnormalities. Eels are found in pannes, and there is a fishery in Musquash.

Indicator species for the rocky intertidal and mudflat: *Ulva* and *Enteromorpha* are good indicators of eutrophication. *Enteromorpha* can appear for short periods and in such cases may indicate temporary eutrophication. Is the presence of *Enteromorpha* or *Ulva* natural? It depends on how long it is present in an area. Long-term presence may indicate a persistent problem and lead to smothering of other species such as clams on mudflats. There is a need for threshold levels of cover before mitigation measures are implemented. We need to set thresholds to identify how much change is too much. At what point does eutrophication become a problem of concern? Essentially the area becomes degraded and species poor with eutrophication. At intermediate levels it increases species diversity, until a threshold is reached. *Enteromorpha* and *Ulva* can be indicators of eutrophication. *Corophium* should be an indicator species because higher trophic levels depend on it for survival. In the upper Bay of Fundy, areas which are disturbed by clamming show higher numbers of *Corophium*. If the birds are there, this indicates that so is *Corophium*.

Birds as indicator species: Species in the higher trophic levels are good indicators, for example, birds if their species disappears, they would be indicators of change. It could be better to pick a species for an indicator that does not have a varied diet, a species that cannot adapt very well to new situations.The great Blue Heron was given as an example. In addition to the four bird species identified in the workshop document, five other bird species would also be good indicator species. These are the the Black Duck, the Bald Eagle, the Greater Yellowleg and the Nelson Sharp-tailed Sparrow. The Black Duck is an omnivore but tends to be a gramnivore seasonally. Its habitat includes salt marshes, mud flats and tidal creeks. The Bald Eagle is a carnivore-scavenger and is found in all habitats in the Musquash estuary. There is also the need to monitor Bald Eagle nesting in the area. The Greater Yellowleg is a general carnivore, and although a migrant, it has a prolonged resident time in the estuary, in both spring and fall. The American Crow is an omnivore found in all habitats, exclusive of pure marine habitats. The Nelson Sharp-tailed Sparrow is a gramnivore that is restricted to

Spartina patens meadows. This list is not intended to be exhaustive but will now give a total nine species for monitoring purposes.

Gooseberry Island was suggested as a sampling location for bird nesting activity. Eider nests on this island were sampled in 1999. Results show that there were twenty eider nests, no way near the capacity for the island. With eider protection, this should be growing. This would be a good monitoring spot for nesting success, and therefore bird habitat. Gooseberry Island is a good sampling/monitoring location because of the isolation and accessibility. It is hard for the public to access; however because of this it has less human influences.

Sublittoral and Contaminant Monitoring

Sublittoral monitoring: Sublittoral video surveys are low impact, record a host of species and their habitat, and capture a temporal scale, but are limited to macrophytes. Beach seining records the numbers and species of fishes, it is low tech and low cost.

Contaminant Monitoring: *Nereis* works the sediments so it picks up contaminants however, chemical analysis to detect changes, done on a regular basis, are not cost efficient and the methods are difficult. This type of monitoring is most effective if used when an accident happens rather than as routine sampling. In the case of an accident in Saint John Harbour, sampling would be needed in the Musquash Harbour to determine if there is transport into Musquash. Copper has been measured in Musquash and is high as compared to other areas in the Bay of Fundy but this probably is a natural input. But designing a program to monitor contaminants in Musquash is not a good idea.

Specific monitoring needs

(i) A list of all the monitoring being done already in Musquash and for how long it has been done through federal, provincial, municipal and non-governmental organizations programs.
(ii) Objectives of the monitoring program need to be defined because otherwise monitoring becomes reactive and not proactive.
(iii) Defining how indicator species help in monitoring the health of Musquash and state how the information will be used.
(iv) Develop ecosystem health indicators. If the environmental changes are going to be tracked every few years, we need to define an efficient way to do it.

Recommendations

(i) Have a set of fixed stations monitored over time chosen carefully for various ecotypes. These would give real time comparisons and should include a qualitative assessment of activities around those stations.
(ii) Do qualitative assessment around stations at the time that the quantitative sampling is being done.
(iii) Choose places for the fixed stations that are accessible
(iv) Sample at the same time of year. August – September is the best sampling time because settlement of juveniles would have occurred by then.
(v) Monitor species in conjunction with environmental monitoring.

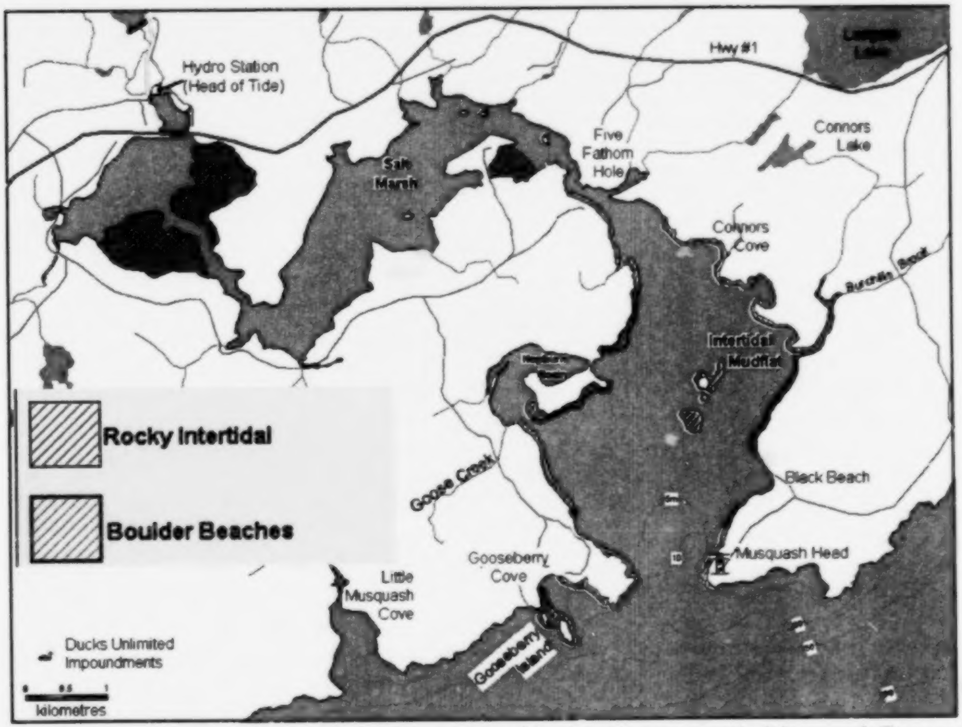
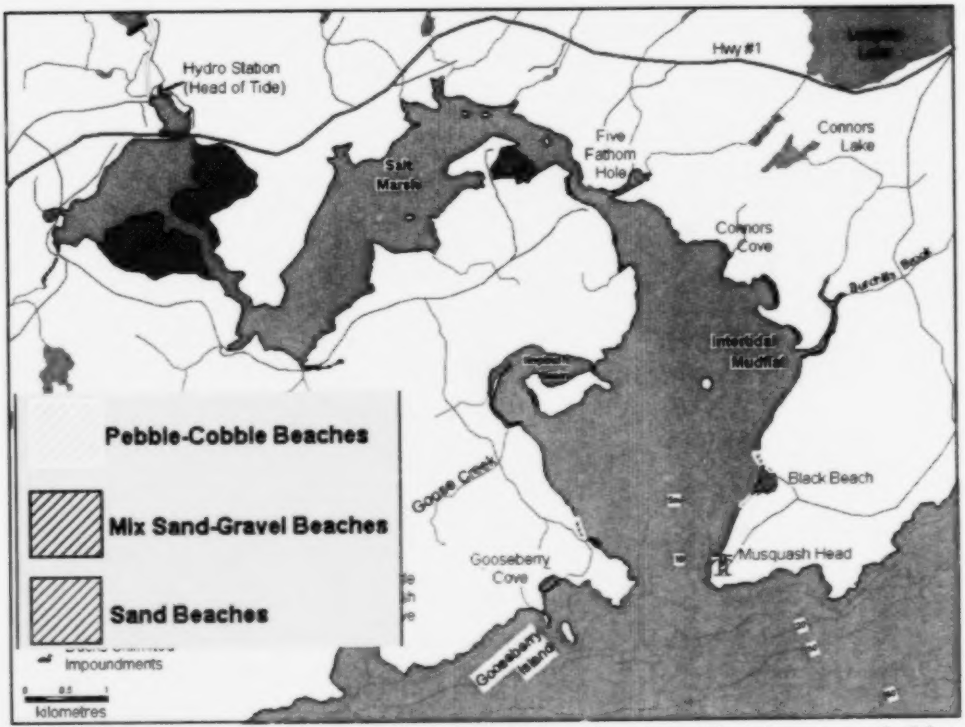

Hwy #1
Hydro Station
(Head of Tide)
Salt
Marsh
Five
Fathom
Hole
Connors
Lake
Connors
Cove
Burchills Brook
Intertidal
Mudflat
▨ Rocky Intertidal
▨ Boulder Beaches
Goose Creek
Black Beach
Musquash Head
Gooseberry
Cove
Little
Musquash
Cove
Gooseberry
Island
Ducks Unlimited
Impoundments
0 0.5 1
kilometres

Fig. 2.3. Distribution of intertidal rocky and boulder beach ecotypes in Musquash Estuary.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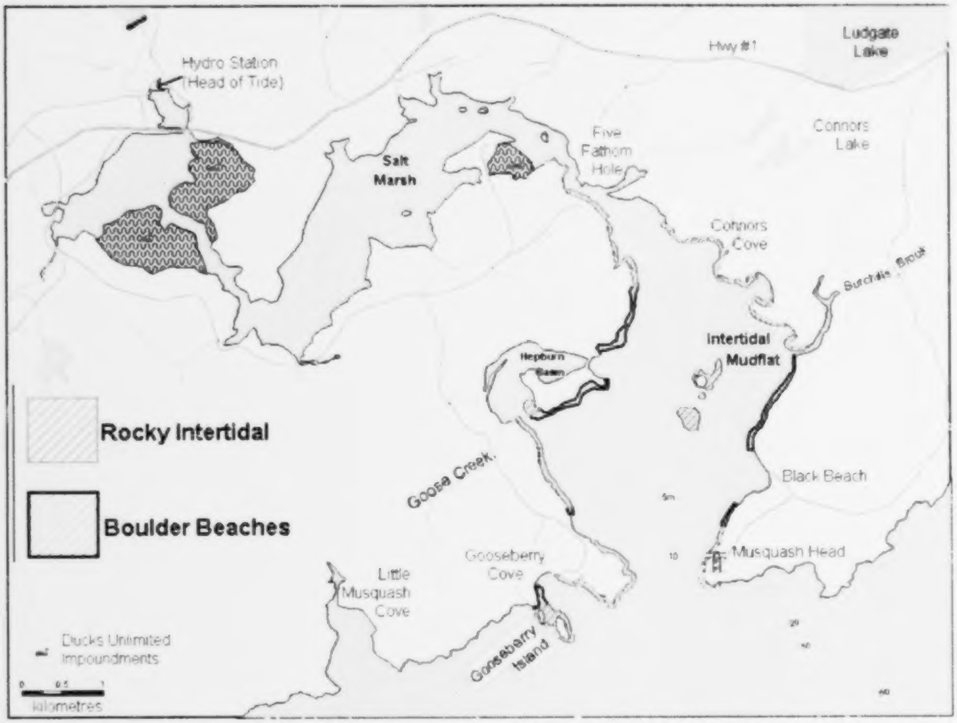
Hydro Station
(Head of Tide)
Salt
Marsh
Five
Fathom
Hole
Connors
Lake
Connors
Cove
Burchills Brook
Intertidal
Mudflat
Pebble-Cobble Beaches
▨ Mix Sand-Gravel Beaches
▨ Sand Beaches
Goose Creek
Black Beach
Musquash Head
Gooseberry
Cove
Gooseberry
Island
Impoundments
0 0.5 1
kilometres

Fig. 2.4. Distribution of pebble-cobble, mix sand-gravel, and sand beach ecotypes in Musquash Estuary.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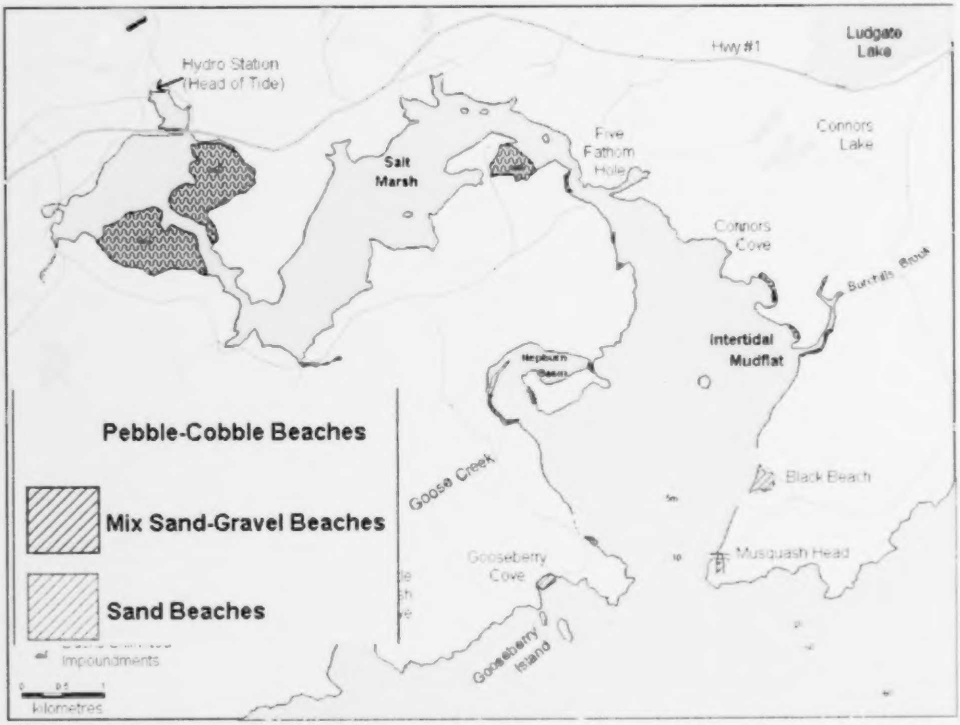
Salt Marsh
Five Fathom Hole
Connors Lake
Connors Cove
Burchills Brook
Intertidal Mudflat
Hepburn Basin
Rocky Intertidal
Boulder Beaches
Goose Creek
Black Beach
5m
10
Musquash Head
Little Musquash Cove
Gooseberry Cove
Gooseberry Island
20
40
60
Ducks Unlimited Impoundments
0 0.5 1
kilometres

Fig. 2.3. Distribution of intertidal rocky and boulder beach ecotypes in Musquash Estuary.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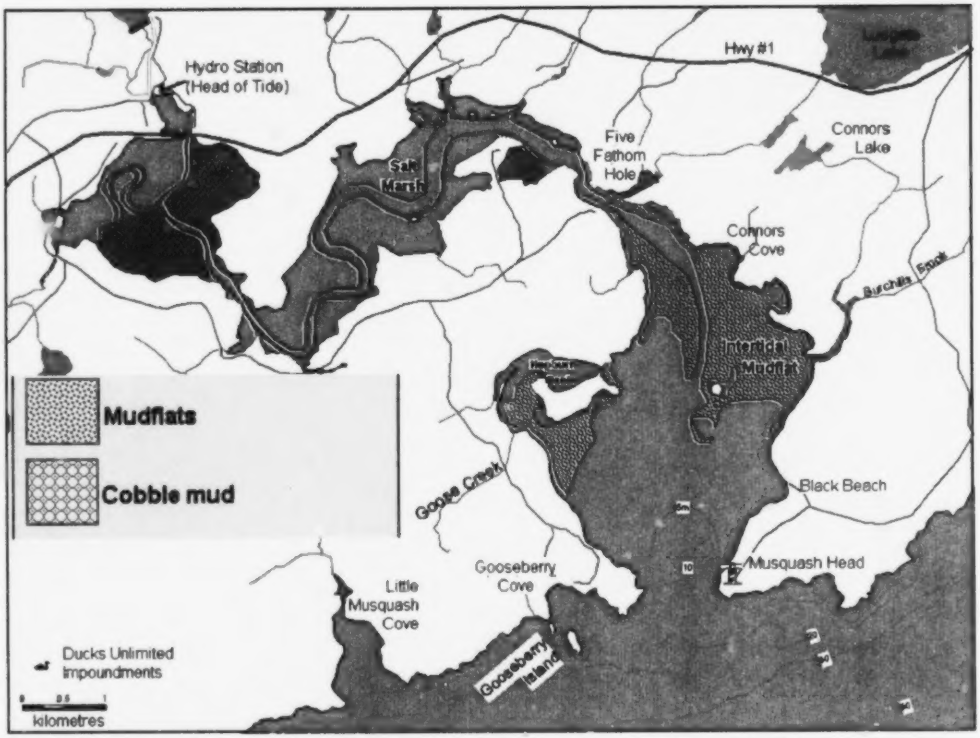
Ludgate Lake
Salt Marsh
Five Fathom Hole
Connors Lake
Connors Cove
Burchills Brook
Intertidal Mudflat
Hepburn Basin
Pebble-Cobble Beaches
Mix Sand-Gravel Beaches
Sand Beaches
Goose Creek
Black Beach
5m
10
Musquash Head
Gooseberry Cove
Gooseberry Island
Impoundments
0 0.5 1
kilometres

Fig. 2.4. Distribution of pebble-cobble, mix sand-gravel, and sand beach ecotypes in Musquash Estuary.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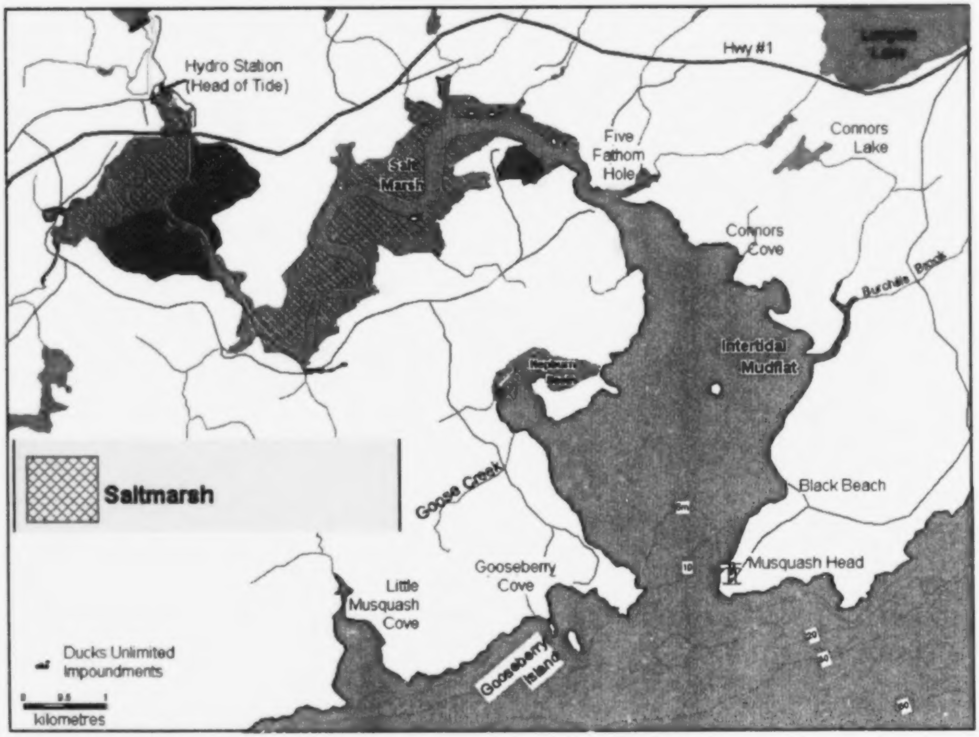
Hwy #1
Salt Marsh
Five Fathom Hole
Connors Lake
Connors Cove
Burchills Brook
Intertidal Mudflat
Mudflats
Cobble mud
Goose Creek
Black Beach
Musquash Head
Gooseberry Cove
Little Musquash Cove
Gooseberry Island
Ducks Unlimited Impoundments
0 0.5 1
kilometres

Fig. 2.5. Distribution of mudflat and cobble-mud ecotypes in Musquash Estuary.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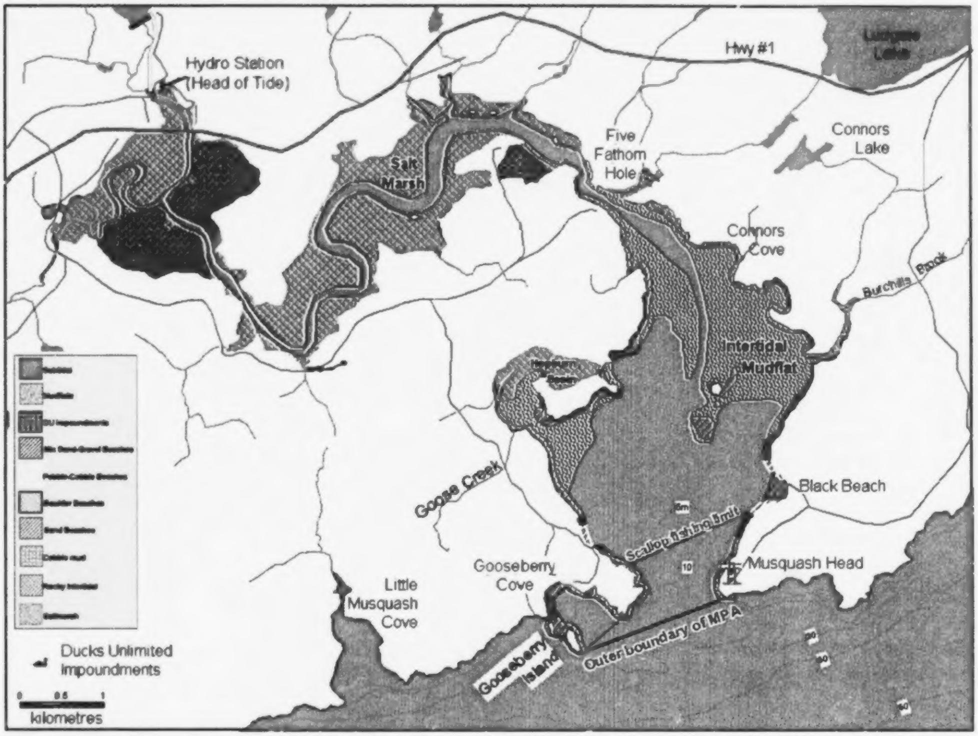
Hwy #1
Salt Marsh
Five Fathom Hole
Connors Lake
Connors Cove
Burchills Brook
Intertidal Mudflat
Saltmarsh
Goose Creek
Black Beach
Musquash Head
Gooseberry Cove
Little Musquash Cove
Gooseberry Island
Ducks Unlimited Impoundments
0 0.5 1
kilometres

Fig. 2.6. Distribution of salt marsh ecotype in Musquash Estuary.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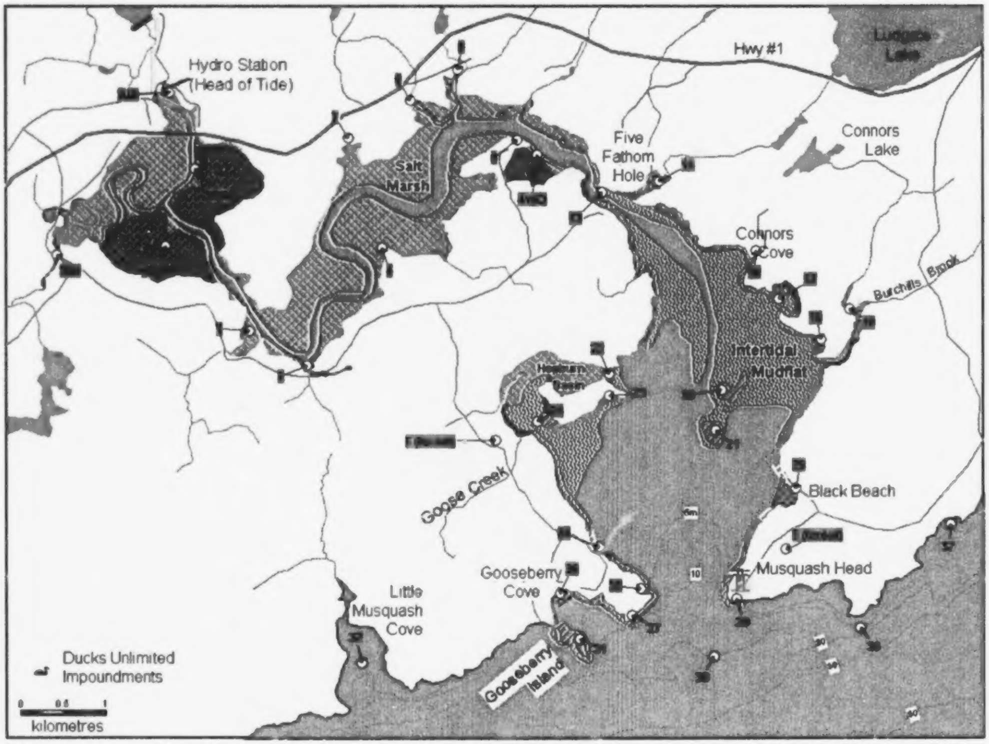
(Head of Tide)
Hwy #1
Ludgate Lake
Salt Marsh
Five Fathom Hole
Connors Lake
Connors Cove
Burchills Brook
Intertidal Mudflat
Black Beach
Goose Creek
Scallop fishing limit
Musquash Head
Gooseberry Cove
Little Musquash Cove
Outer boundary of MPA
Gooseberry Island
5m
10
30
Ducks Unlimited Impoundments
0
0.5
1
kilometres

Fig. 2.7. The distribution of the various ecotypes in the Musquash Estuary.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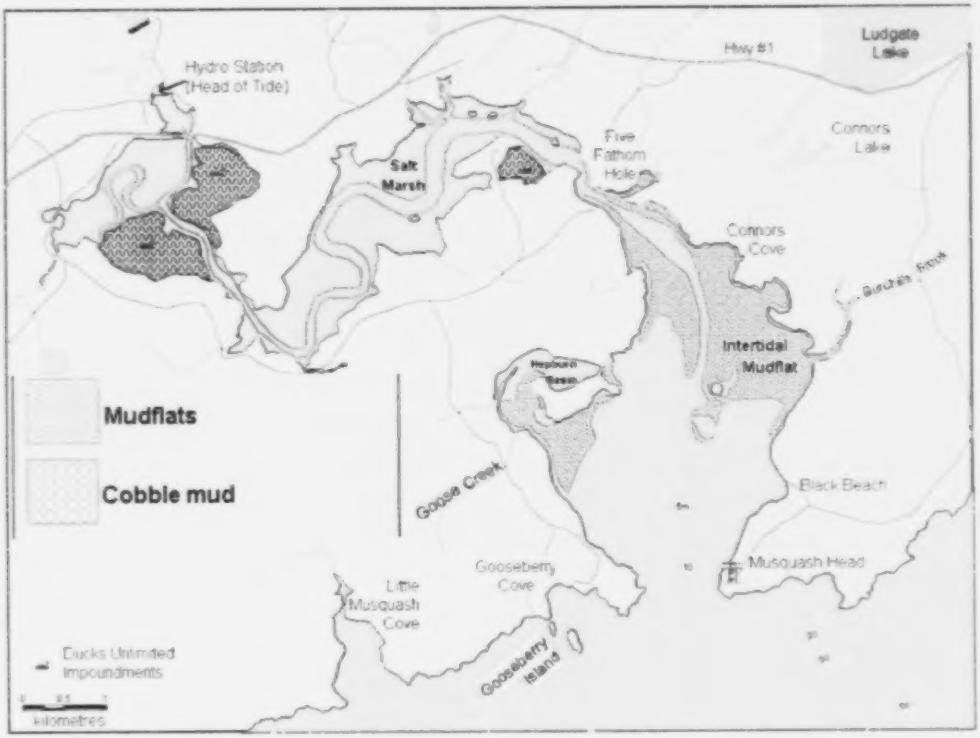
Salt Marsh
Five Fathom Hole
Connors Lake
Connors Cove
Burchills Brook
Intertidal Mudflat
Black Beach
Goose Creek
Musquash Head
Gooseberry Cove
Little Musquash Cove
Gooseberry Island
5m
10
30
21
Ducks Unlimited Impoundments
0
0.5
1
kilometres

Fig. 2.8. Showing the locations from which bird observations were done by Deichmann [16].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Salt Marsh
Five Fathom Hole
Connors Lake
Connors Cove
Burchills Brook
Intertidal Mudflat
Hepburn Basin
Mudflats
Cobble mud
Goose Creek
Black Beach
Musquash Head
Gooseberry Cove
Little Musquash Cove
Gooseberry Island
Ducks Unlimited Impoundments
0 0.5 1
kilometres

Fig. 2.5. Distribution of mudflat and cobble-mud ecotypes in Musquash Estuary.

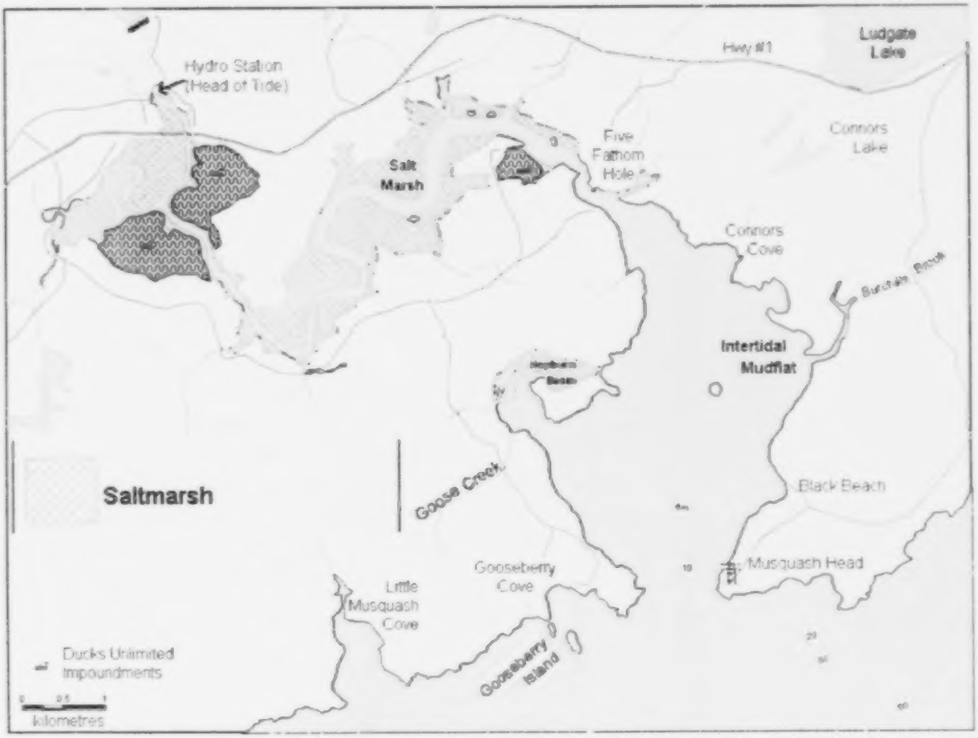
Hydro Station (Head of Tide)
Hwy #1
Ludgate Lake
Salt Marsh
Five Fathom Hole
Connors Lake
Connors Cove
Burchills Brook
Intertidal Mudflat
Hepburn Basin
Saltmarsh
Goose Creek
Black Beach
Musquash Head
Gooseberry Cove
Little Musquash Cove
Gooseberry Island
Ducks Unlimited Impoundments
0 0.5 1
kilometres

Fig. 2.6. Distribution of salt marsh ecotype in Musquash Estuary.

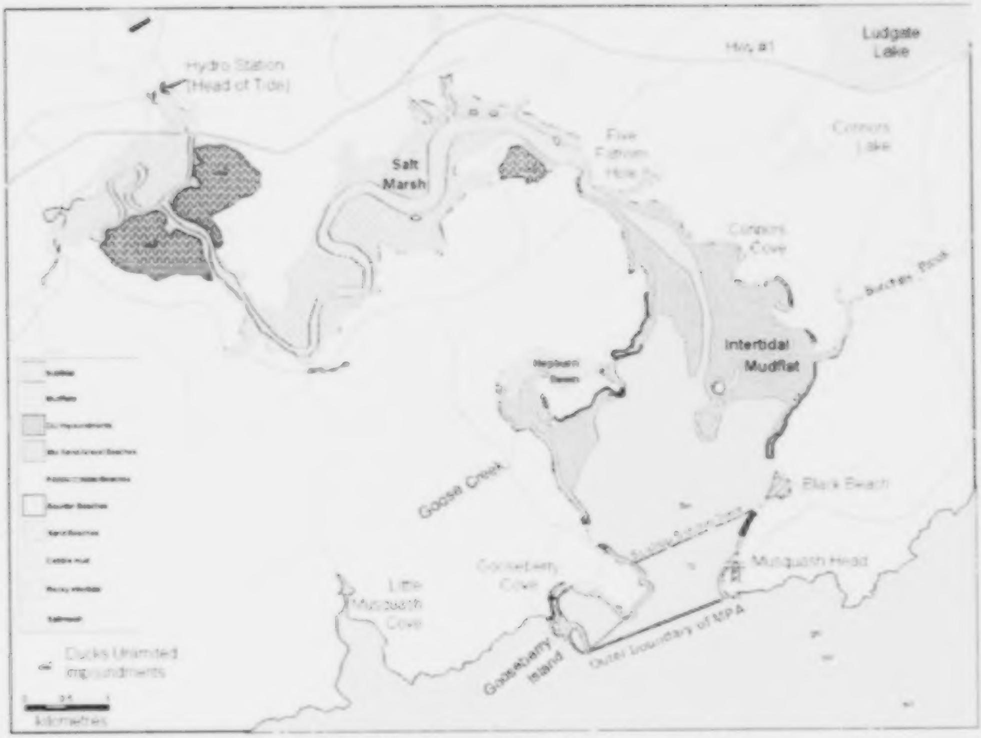
Ludgate Lake
Hwy #1
Hydro Station (Head of Tide)
Salt Marsh
Five Fathom Hole
Connors Lake
Connors Cove
Hepburn Basin
Intertidal Mudflat
Black Beach
Goose Creek
Gooseberry Cove
Little Musquash Cove
Musquash Head
Gooseberry Island
Outer boundary of MPA
Ducks Unlimited impoundments
kilometres

Fig. 2.7. The distribution of the various ecotypes in the Musquash Estuary.

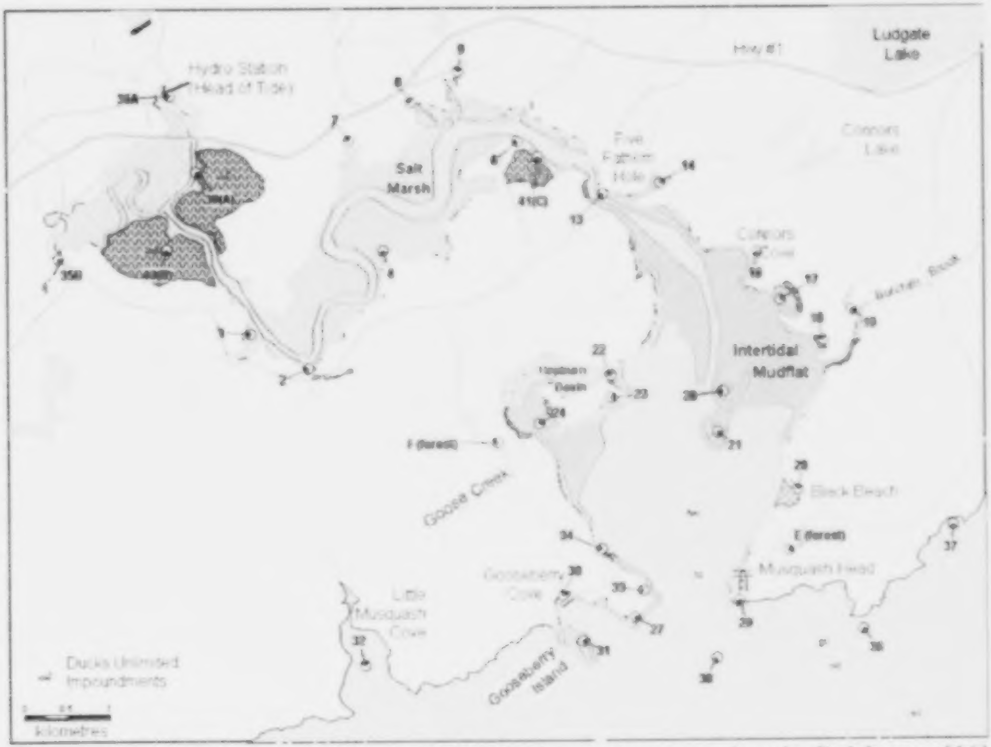
Ludgate Lake
Hwy #1
Hydro Station (Head of Tide)
36A
8
9
7
Salt Marsh
6
41(C)
Five Fathom Hole
13
14
Connors Lake
Connors Cove
16
17
18
19
35B
4
3
2
22
Hepburn Basin
23
20
32A
Intertidal Mudflat
21
F (forest)
Goose Creek
28
Black Beach
E (forest)
37
34
30
33
27
Gooseberry Cove
Musquash Head
29
Little Musquash Cove
32
31
38
36
Gooseberry Island
Ducks Unlimited impoundments
kilometres

Fig. 2.8. Showing the locations from which bird observations were done by Deichmann [16].

Acknowledgements

We would like to thank all the experts who participated and shared their views with us at the workshop. RS would like to thank Drs. Deb MacLatachy and Bruce MacDonald for feedback on possible indicator species and Jo-Anne Stevens for reviewing the species lists. Our thanks also go to Max Westhead for her suggestions on improving this document and to Dave Duggan for feedback on the organization of the contents. Debi Campbell assisted in the editing and formatting of the final document.

References

1. Singh, R., M.-I. Buzeta, M. Dowd, J.L. Martin, M. LeGresley 2000. *Ecological Overview of Musquash Estuary: a proposed Marine Protected Area.* Can. Man. Rep. Fish. Aquat. Sci. **2538**: 39 pp.
2. Stevens, J.A. 1997 (unpublished). *UNBSJ Marine Biology Field Course intertidal species list and salt marsh zonation.* University of New Brunswick, Saint John, NB.
3. Carlisle, B.K., et al. 2002. *A Volunteer's Handbook for Monitoring New England Salt Marshes.* Massachusetts Office of Coastal Zone Management, Boston, MA.
4. Stevens, J.A. 1997 (unpublished). *UNBSJ Marine Biology Field Course intertidal species list and salt marsh zonation.* University of New Brunswick, Saint John, NB. (*Eds. Note: Same as #2*)
5. Thomas, M.L.H. 1973. *An ecological survey of the intertidal zone from Cape Spencer to Point Lepreau, N.B.* Pages 354-424. In: L.E.I.S.S. Committee (Editors) *An appraisal of the environmental consequences of the developments proposed for Lorneville, New Brunswick.* Canada Department of the Environment; New Brunswick, Department of Fisheries and Environment.
6. Thomas, M.L.H. and F.H. Page. 1983. *Grazing by the gastropod,* Lacuna vincta *in the lower intertidal area at Musquash Head, New Brunswick, Canada.* J. Mar. Biol. Assoc. U. K. **63**: 725-736.
7. MacKay, A.A. 1975. *Lorneville Benthos, 1974: A survey of the marine resources of the Lorneville Area New Brunswick, Canada, with particular emphasis on the benthic flora and fauna, and water quality.* Marine Research Associates, Deer Island, NB. 123 pp.
8. Thomas, M.L.H. 1983. *Salt Marsh Systems.* Pages 35-73. In: M.L.H. Thomas (Editor). *Marine and coastal systems of the Quoddy Region, New Brunswick.* Can. Spec. Publ. Fish. Aquat. Sci. 64: 306 pp.
9. Hinds, H. 1999. *A. vascular plant survey of the Musquash Estuary in New Brunswick, Canada.* Prepared for the Conservation Council of New Brunswick: Fredericton, NB. 27 pp.
10. Thomas, M.L.H. 1983. *Tidal Pool Systems.* Pages 95-106. In: M.L.H. Thomas (Editor). *Marine and coastal systems of the Quoddy Region, New Brunswick.* Can. Spec. Publ. Fish. Aquat. Sci. 64: 306 pp.
11. Thomas, M.L.H. 1983. *Rocky Intertidal Communities.* Pages 107-118. In: M.L.H. Thomas (Editor). *Marine and coastal systems of the Quoddy Region, New Brunswick.* Can. Spec. Publ. Fish. Aquat. Sci. 64: 306 pp.
12. Steele, D. 1983. *Coarse Sedimentary Shores.* Pages 74-94. In: M.L.H. Thomas (Editor). *Marine and coastal systems of the Quoddy Region, New Brunswick.* Can. Spec. Publ. Fish. Aquat. Sci. 64: 306 pp.

13. Gratto, G.W. 1986. *Interactions between vertebrate predators their benthic prey on an intertidal mudflat.*, PhD Thesis in *Biology*. University of New Brunswick: Fredericton, NB.
14. Wildish, D.J. 1983. *Sublittoral sedimentary substrates.* Pages 140-155. In: M.L.H. Thomas (Editor). *Marine and coastal systems of the Quoddy Region, New Brunswick.* Can. Spec. Publ. Fish. Aquat. Sci. 64: 306 pp.
15. Wildish, D.J. 1977. *Sublittoral macro-infauna of Musquash Estuary.* Fish. Mar. Serv. MS. Rep. **1463**: 13 pp.
16. Deichmann, H. 1999. *A survey of bird life in the Musquash Estuary on the Bay of Fundy New Brunswick.* Prepared for the Conservation Council of New Brunswick. Conservation Council of New Brunswick, Fredericton, NB. 69 pp.
17. Anon. 1970. *Report on the task force - Operation Oil.* Vol. II. Ministry of Transport, Ottawa, Canada. 104 pp.
18. Thomas, M.L.H.1972 (Unpublished Manuscript). *Effects of "Bunker-C" oil on intertidal and lagoonal biota in Chedabucto Bay, Nova Scotia.* University of New Brunswick, Saint John, NB. 14 pp.
19. Smith, J.E. 1968. *Torrey Canyon disaster and marine life.* Mar. Biol. Assoc. UK. Cambridge University Press. 196 pp.
20. Pollock, L.W. 1998. *A practical guide to the marine animals of northeastern North America.* Rutgers University Press, New Brunswick, N.J. x + 367 pp.
21. Grassle, J.F. and J.P. Grassle. 1974. *Opportunistic life histories and genetic systems in marine benthic polychaetes.* J. Mar. Res. **32**: 253-284.
22. Samuelson, G.M. 2001. *Polychaetes as indicators of environmental disturbance on subarctic tidal flats, Iqualit, Baffin Island, Nunavut Territory.* Mar. Poll. Bull. **42**: 733-741.
23. Reise, K. 1985. *Tidal Flat Ecology: An Experimental Approach to Species Interactions*. Springer, Berlin.
24. Nybakken, J. 1988. *Marine Biology: An Ecological Approach*. Harper & Row, New York.
25. Raposa, K. 2003. *Overwintering habitat selection by the mummichog,* Fundulus heteroclitus, *in a Cape Cod (USA) salt marsh.* Wetlands Ecology and Management **11**: 175-182.
26. Ranasinghe, J.A, D.E. Montagne, S.B. Weisberg, M. Bergen, R.G. Welardel. 2003. *Variability in the identification and enumeration of marine benthic invertebrate samples and its effect on benthic assessment measures.* Environ. Monitoring and Assessment **81**: 199-206.
27. Warwick, R.M., T.H. Pearson, and Ruswahyuni. 1987. *Detection of pollution effects on marine macrobenthos: further evaluation of the species abundance/biomass method.* Mar. Biol. **95**: 193-200.
28. Washington, H.G. 1984. *Diversity, biotic and similarity indices: a review with special relevance to aquatic ecosystems.* Water Resources **19**: 653-694.
29. Schiller, A., et al., 2001. *Communicating ecological indicators to decision makers and the public.* Conserv. Ecol. **5:** 19 [online] URL: http://www.consecol.org/vol5/iss1/art19.
30. Hunsaker, C.T. and D.E. Carpenter. 1990. *Ecological indicators for the Environmental Monitoring and Assessment Program*. Vol. EPA/600/3-90/060. Office

of Research and Development, US EPA, Research Triangle Park, North Carolina, USA.

NEXT STEPS

The information provided in this publication is intended to document the progress made in the development of an ecosystem framework for Musquash MPA. There are several outstanding tasks to be completed including the identification of all the keystone/indicator species in each of the ecotypes. A few of the species have been identified in the workshop of experts; however, the list is incomplete. The life history characteristics of several species from each ecotype are included in Appendix A. This information will be useful in the identification of other keystone/indicator species. As indicated in the workshop summary, five additional birds were suggested as keystone species and the life history characteristics of these species should also be researched and collated.

The workshop on keystone/indicator species identification produced several suggestions on the way forward but the actual species were not identified for many of the ecotypes. Another consultation of experts is needed to identify the keystone/indicator species and this may be best achieved via one-to-one meetings with individuals. Alternatively, based on the results of this first workshop, the next steps would be to use the species already researched and develop objectives for monitoring each species or suite of species. These can then be presented for feedback from experts at a second workshop. Additionally, the framework should also outline the objectives, methodology and possible stressors for change.

The following table provides the status for the tasks identified in Chapter 1 for the development of an ecosystem framework. The tasks to be completed are indicated.

Table 3.0. Framework development task list for Musquash Ecosystem Framework.

Task	Activity	Description	Completed
1	Collect and Review	Collection of all existing and relevant literature, scientific studies, management papers, and additional materials.	Yes
2	Ecotype Preparation	Based on various existing ecotyping methods, select / modify one for Musquash.	Yes
3	Identify Ecotypes	Apply ecotyping methodology to Musquash to define and map relevant ecotypes for the project area.	Yes
4	Species Information	Create a species list by season and trophic level, and identify the relevant ecotypes used by each species at each life stage.	Yes[1]
5	Species Selection	Select key / foundation species to be used in the framework based on scientific relevance, and input from stakeholders. Confirm that the species selected are easily related to identified ecotypes.	Partial[2]
6	Species Parameter Boundaries	For each key / foundation species identified for use, prepare a comprehensive list of the physical, chemical, and biological habitat parameter ranges. Where feasible this should be numeric and based on scientific literature.	Partial[3]

7	Assemblage Parameter Boundaries	Set the parameter boundaries for the assemblage of species found in each ecozone by season	No
8	Existing Parameter Measures	Compare existing habitat parameter measures for Musquash Estuary with those ranges identified above and nsure that they support one another.	No
9	Gap Analysis	Identify information gaps on various parameters for Musquash.Identify and analyze gaps in existing information from previous tasks, and determine significance for implementation of the ecosystem framework	No
10	Develop a comprehensive reference document	Compile a step by step document of all previous steps and findings to demonstrate the background work that supports the final Musquash Ecosystem Framework Document. These steps will become the appendices to the final user document.	Partial
11	Develop Musquash Ecosystem Framework Document	Compile a reference document for managers that outlines appropriate questions to ask proponents, outlines how to select parameter boundaries for specific activities, outlines options for consideration in the decision making process. The Framework document will also provide all current ecosystem material that needs to be referenced in the decision making process.	Partial

[1] Need to research and collate information on the species identified by experts at the Musquash Key/Indicator Species Workshop (five additional species of birds).

[2] Only a few species identified at the workshop. Need another consultation to identify all the key/indicator species from each of the ecotypes.

[3] A list of the physical, chemical, and biological habitat parameter ranges can be developed from the already researched species information once the key/indicator species are identified after consultation with experts.

APPENDIX 1

All of the following information are taken from the "Bay of Fundy, salt marsh community habitat profile", by C.M. Hawkins & R.J. Rutherford (1997), unpublished DFO habitat management reference document (March 1997).

Monthly mean Sea Surface Temperature[1]

Lower Bay of Fundy

Month	Temperature °C
January	2.0
February	0.1
March	0.4
April	4.0
May	5.8
June	8.6
July	11.5
August	14.0
September	12.4
October	10.6
November	7.2
December	4.2

Notes: 1. for waters of < 12 m

Reference

Pertie, B. and F. Jordan. 1993. Nearshore shallow water temperature atlas for Nova Scotia. Can. Tech. Rept. Hydrogr. Ocean Sci. 145: v + 84 p.

Substrate composition

Table A1.5

Soils of Canadian Salt Marshes (10) %

Locality	Coarse Sand	Fine Sand	Silt	Clay	Humus	Moisture
Fundy Marshes						
Timothy Marsh	4.40	31.54	46.55	8.58	6.50	2.2
Low Marsh	0.68	3.2	67.84	10.53	10.92	2.6
Freshly deposited Marsh	5.12	49.49	26.52	9.66	6.2	1.8
Blue Surface Mud	27.2	40.09	31.23	15.2	7.36	3.16
River Habitant, Nova Scotia	1.74	40.07	31.51	5.82	3.2	3.4

Chapman, V.J. 1960. Salt Marshes and Salt Deserts of the World. Leonard Hill Books Ltd. Interscience Publishers Inc., New York. 392 pp.

Table A1.7

Species Life Requirements/Habitats New Brunswick Bay of Fundy		
Species:	*Spartina alterniflora* (Cord Grass)	Source ( )
Abiotic Factors:		
Temperature	- survives four months below freezing each year	(2)
Salinity	- prefers moderate salinity (NaCl) concentrations and places high demands on iron supplies	(1)
Oxygen	- of concern in the anoxic substrate	
Substrate Preference	- colonizes clayey to sandy substrates with variably thick silt cover - does not grow on sandy substrates	(1)
Water Currents and Tides	- on low sites covered by water 10 -17 hours per day - avoids areas of turbulent water	(1)
Cover	- in dense stands so thick that sediment surface receives little light	(1)
Biotic Factors:		
Reproduction Time	- perennial plant	(1)
Reproduction Habitat	- non-sandy, quiet waters of moderate salt concentration	(1)
Reproduction	- by seeds and rhyzome roots	(1)
General Traits	- attains height of 50 to 100 cm	(1)
Other	- stands may produce marine peats - mature stands of this species at 20 to 30 ppt reach 4 to 5 feet in height	(1) (1)

References

(1) Thannheiser, D. 1984. The Coastal Vegetation of Easter Canada. Memorial University of Newfoundland. Occasional Papers in Biology. 8: 212 pp.

(2) Long, S.P. and C.F. Mason. 1983. Saltmarsh Ecology. Blackie, London. 160 pp.

Table A1.9

Species Life Requirements/Habits: New Brunswick Bay of Fundy		
Species:	*Corophium volutator*	Source ( )
Abiotic Factors:		
Temperature	- lowest lethal temperature -3.3 °C for summer generation and -8.4 for winter generations - upper lethal temperature 38.7 °C at 20 ppt	(10)
Salinity	- euryhaline 2 to 50 ppt, minimum 2 ppt , 10 to 30 ppt, 5 to 30 ppt maximum growth rates - low salinity tolerance (2 to 10 ppt) - 20 ppt required to lay eggs - can survive 500 hr at 2 to 50 ppt	(2),(4),(5) (10) (10) (11)
Oxygen	- no data on upper and lower limits found to date	
Substrate Preference	- prefers sediments of predominantly silt-sized particles of less than 44 microns	(9)
Water Currents and Tides		
Use of Cover	- burrows in sediments	(9)
Biotic Factors:		
Spawning Time	- late June and late August through September	(1), (8)
Spawning Habitat		
Eggs	- average brood size of 38 per female	(1)
Foods	- mud and organic debris - selective deposit feeder	(5), (6) (3), (9)
Other	- important food source for migrant shorebirds	(7)

References

(1) Linkletter, L. and P.W. Hicklin. 1980. Aspects of the life history and reproductive biology of *Corophum volutator* (Pallas), in the Upper Bay of Fundy. Can. Wild. Serv. Preliminary Report. CWS. Sackville, New Brunswick. 36 pp.

(2) McKlusky, D.S. 1969. The oxygen consumption of *Corophium volutator* in relation to salinity. Comp. Biochem. Physiol. 29: 734-753.

(3) Nielsen, M. and L. Koefoed. 1982. Selective feeding and epopsammic browsing by the deposit feeding amphipod *Corophium volutator*. Mar. Ecol. Prog. Ser. 10: 81-88.

(4) McLusky, D.S. 1970. Salinity preference in *Corophium volutator*. J. Mar. Biol. Ass. 50: 747-752.

(5) McLusky, D.S. 1968. Some effects of salinity on the distribution and abundance of *Corophium volutator* in the Ythan estuary. J. Mar. Biol. Ass. 48: 443-454.

(6) Meadows, P.S. and A. Reid. 1966. The behaviour of *Corophium volutator* (Crustacea: Amphipoda). J. Zool. Soc. Lond. 150: 387-399.

(7) Hicklin, P.W. and P.C. Smith. 1979. The diets of five species of migrant shorebirds in the Bay of Fundy. Proc. N.S. Inst. Sci. 29: 483-488.

(8) Gratto, G.W., M.L.H. Thomas and J.S. Bleakney. 1983. Growth and production of the intertidal amphipod *Corophium volutator* (Pallas) in the inner and outer Bay of Fundy. Proc. N.S. Inst. Sci. 33: 47-55.

(9) Hawkins, C.M. 1985. Population carbon budgets and the importance of the amphipod *Corophium volutator* in the carbon transfer on a Cumberland Basin mudflat, Upper Bay of Fundy, Canada. Neth. J. Sea. Res. 19: 165-176.

(10) Mills, A. and J.D. Fish. 1980. Effect of salinity and temperature on *Corophium volutator* and *C. arenarium* (Crustacea: Amphiopoda), with particular reference to distribution. Mar. Biol. 58: 153-161.

(11) McLusky, D.S. 1967. Some effects of salinity on the survival, moulting and growth of *Corophium volutator*. J. Mar. Biol. Ass. 47: 607-617

Table A1.10

Species Life Requirements/Habits: New Brunswick, Bay of Fundy		
Species:	*Macoma balthica*	Source ( )
Abiotic Factors:		
Temperature	- ambient temperature range 10 to 14 °C , range 0 to 10°C best for growth	(3), (4)
Salinity	- in waters > 0.4 ppt - in salinities as low as 5 ppt	(1) (6)
Oxygen	- not tolerant of low oxygen	(1)
Substrate Preference		
Water Currents and Tides		
Use of Cover	- burrows	
Biotic Factors:		
Spawning Time	- April to end of May in Europe	(4)
Spawning Habitat		
Eggs		
Foods	- facultative filter-feeder and surface deposit feeder	(5), (2)
Other		

References

(1) Wenne, R. and Styczynska-Jurewicz, E. 1985. Microgeographic differentiation in condition and biochemical composition of *Macoma balthica* (L.) from the Gadansk Bay (South Baltic). Pol. Arch. Hydrobiol. 32: 197-194.

(2) Green, R.H., S.M. Singh, B. Hicks and J.M. Cuaig. 1983. An arctic intertidal population of *Macoma balthica* (Mollusca, Pelecypoda): genotypic and phenotypic components of population structure. Can. J. Fish. Aquat. Sci. 40: 1360-1371.

(3) de Wilde, P.A.W.J. 1975. Influence of temperature on behaviour, energy metabolism and growth of *Macoma balthica* (L.) Pages 239-256. In: Barnes, H. (Ed.). 9th Europ. Symp., Oban, Scotland. Aberdeen, University Press.

(4) Wenne, R. 1985. Microgeographic differentiation of the reproductive cycle of *Macoma balthica* (L.) in the Gdansk Bay (South Baltic), and the relationship between this cycle and energy reserve changes. Pol. Arch. Hydrobiol. 32: 47-63.

(5) Berrill, M. and D. Berrill. 1981. The North Atlantic Coast: Cape Cod to Newfoundland. Sierra Club Books, San Francisco. 464 pp.

(6) Gosner, K.L. 1978. A Field Guide to the Atlantic Seashore, from the Bay of Fundy to Cape Hatteras. Houghton Mifflin Company, Boston. 329 pp.

Table A1.11

Species Life Requirements/Habits New Brunswick Bay of Fundy		
Species:	*Gasterosteus aculeatus* (Threespine stickleback)	Source ( )
Abiotic Factors:		
Temperature		
Salinity	- lives whole life under estuarine conditions but at home under full sea water salinity and fresh water	(2)
Oxygen		
Substrate Preference	- tolerant of marine, brackish and freshwaters mainly occupying shallow areas in coastal areas	(1)
Water Currents and Tides		
Use of Cover	- hide in rockweed and, eelgrass	(2)
Biotic Factors:		
Spawing Time	- takes place in fresh water during warm summer months June or July - many males die after spawning	(1), (2)
Spawning Habitat	- build nests of twigs	(1)
Eggs	- 1.5 to 1.7 mm in diameter, adhesive and yellow, semi-opaque	(1)
Foods	- voracious feeder on small invertebrates, copepods, euphausiids and isopods in the sea	(1)
Other		

References

(1) Scott, W.B. and M.G. Scott. 1988. Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 731 pp.

(2) Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish Wild. Serv. Fish Bull. 53: 1-577 (Fish Bull. 74).

Table A1.12

Species Life Requirements/Habits New Brunswick Bay of Fundy		
Species:	*Gasterosteus wheatlandi* (Blackspotted stickleback)	Source ( )
Abiotic Factors:		
Temperature		
Salinity	- almost strictly marine	(1)
Oxygen		
Substrate Preference	- in shallow water of 2.7 m or less	(1)
Water Currents and Tides		
Use of Cover	- swims near floating seaweed	(1)
Biotic Factors:		
Spawning Time	- mid-summer	(1)
Spawning Habitat	- builds nests	(1)
Eggs	- vary in size from 1.2 to 1.5 cm in diameter	(1)
Foods	- little information available but primarily small invertebrates - likely similar diet to the threespine stickleback	(1)
Other		

References

(1) Scott, W.B. and M.G. Scott. 1988. Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 731 pp.

Table A1.13

Species Life Requirements/Habits New Brunswick Bay of Fundy		
Species:	*Fundulus herteroclitus* (Mummichog)	Source ( )
Abiotic Factors:		
Temperature	- upper lethal at 14 ppt, 34 °C	(1)
Salinity	- common over a wide range of salinities upper limits of at 10 °C of 106 to 120.3 ppt	(1)
Oxygen	- very tolerant of low oxygen concentrations - can survive in stagnant waters for long periods	(1), (2)
Substrate Preference	- marshy areas and brackish waters with submergent or emergent vegetation	(1), (2)
Water Currents and Tides	- tidal currents influence distribution	(2)
Use of Cover	- sheltered shores and in Spartina (eelgrass) beds in water	(2)
Biotic Factors:		
Spawing Time	- spawning occurs in shallow waters in from April to August depending on water temperature	(1)
Spawning Habitat	- eggs may be deposited on aquatic plants, on masses of algae, in sand and mud, in mussel shells	(1), (2)
Eggs	- about 2.1 mm in diameter, spherical, pale yellow and spherical and adhesive	(1)
Foods	- omniverous, variety of small crustaceans, polychaetes, insect larvae and veretable matter	(1)
Other		

References

(1) Scott, W.B. and M.G. Scott. 1988. Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 731 pp.

(2) Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish Wild. Serv. Fish Bull. 53: 1-577 (Fish Bull. 74).

Table A1.14

Species Life Requirements/Habits New Brunswick Bay of Fundy Shore		
Species:	*Littorina saxatilis* (Rough periwinkle)	Source ( )
Abiotic Factors:		
Temperature	- coma in air 34 °C - coma in water 40 °C - death in air 32 °C - death in water 40 °C	(2) (2) (2) (2)
Salinity	- no specific data found to date for this species	
Oxygen	- throughout the temperature range of 22-42 °C the respiratory rates in air were higher than in water - can survive by air breathing	(2) (1)
Substrate Preference		
Water Currents and Tides		
Use of Cover		
Biotic Factors:		
Spawing Time		
Spawning Habitat		
Eggs	- sexes separate and viviparous (produce live young not eggs)	(3)
Foods	- feeds on *Calothrix* , the bluegreen algae of the black zone	(1)
Other	- smallest of the three Littorinid species	(1)

References

(1) Berrill M. and D. Berrill. 1981. The North Atlantic Coast: A Sierra Club Naturalist's Guide. Sierra Club Books, San Francisco. 464 pp.

(2) Sandison, E.E. 1967. Respiratory response to temperature and temperature tolerance of some intertidal gastropods. J. Exp. Mar. Biol. Ecol. 1: 271-281.

(3) Gosner, K.L. 1978. A Field Guide to the Atlantic Seashore. Houghton Mifflin Co., Boston. 309 pp.

Table A1.15

Species Life Requirements/Habits New Brunswick Bay of Fundy		
Species:	*Cancer maenas* (Green shore crab)	Source
Abiotic Factors:		
Temperature	- not active at temperatures < 2 °C - activity reduced at < 7 °C	(3) (3)
Salinity	- lethal below 11 ppt	(3)
Oxygen	- no data found to date	
Substrate Preference	- intertidally	(2)
Water Currents and Tides	- assumed important for larval dispersion (CMH)	
Use of Cover	- burry in sediments - under rocks and ocean debris - under algae (seaweeds)	(3) (4) (4)
Biotic Factors:		
Spawing Time	- ripe females in spring	(2)
Spawning Habitat	- females carry eggs	
Eggs	- no data found to date	
Foods	- clams, mussels, oysters - omnivore	(1) (3)
Other		

References

(1) Elner, R.W. 1989. Crabs of the Atlantic coast of Canada - Underwater World 8p. Communication Directorate, Fisheries and Oceans Canada, Ottawa.

(2) Naylor, E. 1962. Seasonal changes in a population of *Carcinus maenas* (L.) in the littoral zone. J. Anim. Ecol. 31: 601-609.

(3) Ropes, J.W. 1968. The feeding habits of the green crab *Carcinus maenas* (L.). Fish. Bull. 67: 183-203

(4) Berrill M. and D. Berrill. 1981. The North Atlantic Coast: A Sierra Club Naturalist's Guide. Sierra Club Books, San Francisco. 464 pp.

Table A1.16

Species Life Requirements/Habits New Brunswick Bay of Fundy		
Species:	*Gammarus oceanicus* (Amphipod)	Source
Abiotic Factors:		
Temperature	- not found in temperatures > 2.0 °C	(1)
Salinity	- not found in salinities < 2.5 ppt	(1)
Oxygen	- no data found to date	
Substrate Preference	- sheltered moderately exposed intertidal coasts under rocks and algae	(1), (2)
Water Currents and Tides	- no data found to date	
Use of Cover	- hides under rocks and in algae (1) - significant use of rockweed as cover and food (2)	(1) (2)
Biotic Factors:		
Spawing Time	- successive broods December through August (1) - summer (2)	(1) (2)
Spawning Habitat	- no data found to date	
Eggs	- eggs brooded	(2)
Foods	- scavenger	(2)
Other	- possibly the most common of all understory organisms in the intertidal	(2)

References

(1) Steele, D.H. and Steele, V.J. 1972. The biology of *Gammarus* (Crustacea: Amphipoda) in the Northwestern Atlantic VII. The duration of embryonic development in five species at various temperatures. Can. J. Zool. 51: 995-999.

(2) Berrill M. and D. Berrill. 1981. The North Atlantic Coast: A Sierra Club Naturalist's Guide. Sierra Club Books, San Francisco. 464 pp.

Table A1.17

Species Life Requirements/Habits New Brunswick Bay of Fundy		
Species:	*Mytilus edulis* (Blue mussel)	Source
Abiotic Factors:		
Temperature	- minimum temperature for spawning 12 °C	(21)
	- lower lethal 5 °C or less inferred from larval no growth	(8)
	- no growth at 5 °C best between 10 °C and 16 °C retarded at higher temperature	(8)
	- optimal larval growth at 20 °C and 25-35 ppt salinity	(1), (9)
	- optimal temperature for growth 10-20 °C	
	- upper tolerance limit about 26 °C	(10), (17)
	- upper lethal temperature 27 °C - 29 °C	(12)
	- growth can take place at 3 °C to 25 °C	(15),(16),(19),(22)
	- average lethal point 40.4-40.8 °C	(11)
	- young mussels (20-26 mm shell length) grow in 20 to 25 °C	(20) (2)
	- young less cold tolerant than adults	
	- lower lethal > - 10 °C	(24)
	- adult median lethal temperature -12.5 °C to -20 °C	(23), (24), (25)
	with juveniles less cold tolerant than adults -8.0 °C to -12.5 °C	(24)
Salinity	- optimal larval growth at 20 °C and 25-35 ppt salinity	(1), (9)
	- > 15 ppt required for successful fertilization	(4)
	- no growth at 19 ppt	(18)
	- retarded growth at 24 ppt	(18)
	- normal growth at 30-32 ppt	(18)
	- growth at 14 ppt	(18)
	- reduction of growth in salinities > 40 ppt	(12)
	- at 4 to 5 ppt very low growth rates	(13)
Oxygen	- survived 35 days at 10 C with oxygen at 0.15 ml O_2 per litre	(1), (26)
	- if available oxygen drops below 60% saturation mussels are unable to compensate and oxygen uptake then declines rapidly with change in the environmental oxygen concentration	(1)
Substrate Preference	- attaches to a variety of solid substrates including: rocks, stones, dead shells, compact mud	(6)
	- upper limit of distribution primarily a function of the operation of physical factors such as exposure to air and desiccation, especially the young stages, genetics may be also involved (K. Freeman, pers. comm.)	(5)
Water Currents and Tides	- aide in dispersion	(1), (4)
	- marked increase in oxygen consumption with currents increasing from 0.0 to 0.1 m/sec	(14)
Use of Cover	- commonly found under rockweed which is competes for space	(26)
Biotic Factors:		
Spawing Time	- spawning: St Andrews, New Brunswick, mid-June to mid-September (primarily August)	(3)

	- spawning: no difference in spawning time between permanently submerged mussels and those periodically exposed to air	(7)
Spawning Habitat	- spawns into open water sexes separate	(1)
Eggs	- benthic	(4)
Foods	- filter feeders on microplankton	
Other	- cultured for commercial consumption	(1)

References

(1) Newell, R.I.E. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North and Mid-Atlantic)--blue mussel. U.S. Fish Wildl. Ser. Biol. Rep. 82(11.102). U.S. Army Corps of Engineers. TR E1-82-4. 25 pp.

(2) Incze, L.S and R.A. Lutz. 1980. Mussel Culture: An East Coast Perspective. Chapter 5, Pages 99-140. In: Lutz, R.A. (Ed.) Mussel Culture and Harvest: A North American Perspective. Developments in Aquaculture and Fisheries Science 7. Elsevier Scientific Publishing Company, New York. 350 pp.

(3) Battle, H. 1932. Rhythmical sexual maturity and spawning of certain bivalve molluscs. Contr. Can. Biol. Fish. N.S. 7: 257-276.

(4) Field, I.A. 1922. Biology and economic value of the sea mussel - *Mytilus edulis*. U.S. Fish and Wildlife Ser., Fish Bull. 38: 127-260.

(5) Seed, R. 1976. Ecology. Chapter 2, Pages 13-66. In: Bayne, B.L. (Ed.). Marine Mussels: their Ecology and Physiology. International Biological Programme 10. Cambridge University Press, New York. 411 pp.

(6) Lewis, J.R. 1964. The Ecology of Rocky Shores. English Universities Press, London.

(7) Lubet, P. 1957. Cycle sexuel de *Mytilus edulis* L. et *Mytilus galloprovincialis* Lmk. dans le Bassin d'Arcachon (Gironde). Annee biologique. 33: 19-29.

(8) Bayne, B.L. 1965. Growth and delay of metamorphosis of the larvae of *Mytilus edulis* L. Ophelia 2: 1-47.

(9) Hrs-Brenko, M. and A. Calabrese. 1969. The combined effects of salinity and temperature on larvae of the mussel *Mytilus edulis*. Mar. Biol. 4: 224-226.

(10) Couthard, H.S. 1929. Growth of the Sea Mussel. Contr. Can. Biol. Fish. 4: 123-136.

(11) Huntsman, A.G. 1921. The effect of light on growth in the mussel. Trans. Royal Soc. Can. Ser. 3. 15: 23-28. cited in (10)

(12) Jamieson, G.S., I.C. Neish and C.L. Clarke. 1975. Perspectives and development prospects of mussel cultivation in the Maritime Provinces of Canada. Reference AMRL 74-11, Applied Marine Research Limited, Marine Ecology Laboratory, Halifax, Nova Scotia, 75 p.

(13) Remane, A. and C. Schlieper. 1971. Biology of Brackish Water. New York: Wiley-Interscience, 372 pp. cited in Chapter 3. In: Lutz, R.A. (Ed.) Mussel Culture and Harvest: A North American Perspective. Developments in Aquaculture and Fisheries Science, 7 Elsevier Scientific Publishing Company, New York. 350 pp.

(14) Nixon, S.W., C.A. Oviatt, C. Rogers and K. Taylor. 1971. Mass and metabolism of a mussel bed. Oecologia 8: 21-30.

(15) Read, K. R. H. and K. B. Cumming. 1967. Thermal tolerance of the bivalve molluscs *Modiolus modiolus* L., *Mytilus edulis* L., and *Brachidontes demissus* Dillwyn. Comp. Biochem. Physiol. 22: 149-155.

(16) Wells, H.W. and I.E. Gray. 1960. The seasonal occurrence of *Mytilus edulis* on the Carolina coast as a result of transport around Cape Hatteras. Biol. Bull., Woods Hole 119: 550-559.

(17) Lutz, R.A. and B. Porter. 1977. Experimental culture of blue mussels *Mytilus edulis* L. in heated effluent waters of a nuclear power plant. Proceedings, World Mariculture Society 8: 427-445.

(18) Bayne, B.L. 1965. Growth and delay of metamorphosis of the larvae of *Mytilus edulis* L. Ophelia 2: 1-47. (*Ed. Note: same as # 8*)

(19) Bayne,B.L., J. Widdows and C. Worrall. 1977. Some temperature relationships in the physiology of two ecologically distinct bivalve populations. Pages 379-400. In F.J. Vernberg, A. Calabrese, F.P. Thurberg and W.B. Vernberg. (Eds). Physiological Responses of Marine Biota to Pollutants. Academic Press Inc., New York. 462 pp.

(20) Henderson, J. T. 1929. Lethal temperatures of Lamellibranchiata. Contr. Can. Biol. Fish. 4: 397 - 412.

(21) Sutterlin, A, D. Aggett, C. Couturier, R. Scaplen and D. Idler. 1981. Mussel culture in Newfoundland Waters. Mar. Sci. Res. Lab Tech. Rept. 23 Mem.Univ. Nfld. cited In: Witherspoon, N.B. 1986. Environmental effects on reproduction, settlement and survival in two spatially isolated populations of the blue mussel (*Mytilus edulis* L.). Manuscript and Technical Report Series 86-05, Nova Scotia Department of Fisheries. 75 pp.

(22) Stone, H.H., G.V. Hurley and S.S. Coffen. 1987. Development of criteria and methods for the bottom culture of blue mussels. Economic Regional Development Agreement. E.R.D.A. Report No. 3. 85 pp.

(23) Williams, R.J. 1970. Freezing tolerance in *Mytilus edulis*. Comp. Biochem. Physiol. 35: 145-161.

(24) Bourget, E. 1982. Seasonal variations in cold tolerance in intertidal molluscs and relation to environmental conditions in the St. Lawrence Estuary. Can. J. Zool. 61: 1193-1201.

(25) Kanwisher, J.W. 1955. Freezing in intertidal animals. Biol. Bull., Woods Hole 109: 56-63.

(26) Theede, H., A. Ponat, K. Hiroki and C. Schlieper. 1969. Studies on the resistance of marine bottom invertebrates to oxygen-deficiency and hydrogen sulphide. Mar. Biol. 2: 325-337.

(27) Berrill M. and D. Berrill. 1981. The North Atlantic Coast: A Sierra Club Naturalist's Guide. Sierra Club Books, San Francisco. 464 pp.

APPENDIX 2

Table A2.1. Species by Ecotype: Rocky Intertidal (Fig. 2.3).
C / I = Confirmed / Inferred, TG = Trophic group, P = primary producer, SC = scavenger, S = suspension feeder, D = deposit feeder, H = herbivore, C = carnivore, O = omnivore; u = upper midlittoral, m = midlittoral, l = low midlittoral; ll = low littoral; sf = supralittoral fringe; sz = supralittoral zone; smf = submaritime fringe; iz = infralittoral zone.

Species	**Common Name**	**TG**	**C / I**
Lichens	Lichen	P	C [4]
Acarospora fuscata (sz)	Lichen	P	C [4]
Acarospora samaragdula (sz)	Lichen	P	C [4]
Caloplaca elegans (sz)	Lichen	P	C [4]
Caloplaca marina (sz)	Lichen	P	C [4]
Cladonia chlorophaea (sz)	Lichen	P	C [4]
Cladonia coccifera (sz)	Lichen	P	C [4]
Cladonia ecmocyna (smf)	Lichen	P	C [4]
Cladonia leporina (sz)	Lichen	P	C [4]
Lecanora grantii (sz)	Lichen	P	C [4]
Lepraria membranacea (supralit. overhang)	Lichen	P	C [4]
Normandina pulchella (sz)	Lichen	P	C [4]
Parmelia (Xanthoparmelia) conspera (s)	Lichen	P	C [4]
Parmelia saxatilis (sz)	Lichen	P	C [4]
Parmelia sulcata (sz)	Lichen	P	C [4]
Rhizocarpon concentricum (sz)	Lichen	P	C [4]
Rhizocarpon obscuratum (sz)	Lichen	P	C [4]
Verrucaria ceuthocarpa (sz)	Lichen	P	C [4]
Verrucaria maura (sz)	Black encrusting lichen	P	C [4], [5]
Verrucaria microspora (m)	Lichen	P	C [4]
Verrucaria mucosa (m)	Green lichen	P	C [4]
Xanthoria elegans (sz)	Lichen	P	C [4]
Xanthoria parietina (sz)	Orange lichen	P	C [4], [5]
Lichina pygmaea (sz)	Black lichen	P	C [4], [5]
Byrophyta			
Bryum salinum (sz)		P	C [4]
Pohlia elongata (sz)		P	C [4]
Pohlia nutans (sz)		P	C [4]
Tetradantium brownianum (sz)		P	C [4]
Chlorophyta			
Acrosiphonia arcta		P	C [6]
Chaetomorpha linum (m)		P	C [4], [6]
Chaetomorpha melagonium (m)		P	C [4], [6]
Cladophora expansa		P	C [4]
Entermorpha compressa		P	C [4], [6]
Entermorpha intestinalis (m)		P	C [4], [6]
Monostroma grevillei (m)	Sea lettuce	P	C [4], [5]
Monostroma oxyspermum (m)	Sea lettuce	P	C [4], [5]

Species	**Common Name**	**TG**	**C / I**
Praziola stipitata (sf)		P	C [4]
Spongomorpha arcta (m)		P	C[4], [5]
Ulothrix flacca (s)		P	C[4]
Ulva lactuca (m)	Sea lettuce	P	C [4], [6], [7]
Phaeophyta			
Agarum cribrosum (l)	Kelp	P	C [4], [5]
Alaria esculenta (l)		P	C [4]
Ascophyllum nodosum (m)	Knotted Wrack (Rockweed)	P	C [4], [7]
Ectocarpus siliculosus (m)		P	C [4]
Fucus distichus edentatus (l)	Bladder wrack	P	C[4], [5], [6]
Fucus spiralis (u)	Bladder wrack	P	C [8]
Fucus vesiculosus (m)	Bladder wrack	P	C [6], [7], [8]
Fucus vesiculosus evesiculosus (m)	Bladder wrack	P	C [4]
Laminaria digitata (ll)	Kelp	P	C [4], [6]
Laminaria saccharina (ll)	Kelp	P	C [4]
Laminaria longicruris (ll)	Kelp	P	C [5]
Ralfsia fungiformis (m)		P	C [4]
Rhodophyta			
Anfeltia plicata (m)		P	C [4]
Audouinella (Rhodocorten) purpurea (m)		P	C [4]
Ceramium rubrum (l)		P	C [4], [6]
Chondrus crispus (l)	Irish moss	P	C [4], [6], [5]
Corallina officinalis (l)	Feathery pink corraline algae	P	C [4], [6], [5]
Devaleraea (Halosacchion) ramentaceum (l)		P	C [4], [6], [5]
Hildenbrandia prototypus (H. rubra) (m)	Red encrusting algae	P	C [4], [6], [7]
Lithothamnion glaciale (m)	Encrusting red algae	P	C[4], [5], [7]
Mastocarpus stellatus (m)	Agar weed	P	C[4], [6]
M. stellatus 'Petrocelis' phase (m)	Agar weed	P	C[4]
'Petrocelis' (Mastocarpus sporoph.) (l)	Agar weed	P	C [4], [6], [7]
Palmaria palmata (l)	Dulse	P	C[4]
Phymatolithon lenormandii (l)	Pink encrusting corraline algae	P	C [4], [6], [7]
Polysphonia lanosa (m)	Epiphytic red algae	P	C [4], [6], [7]
Polysphonia urceolata (l)		P	C [4]
Porphyra umbilicalis (m)		P	C [4], [5], [6]
Monocotyledonae			
Poa sp.	Grass	P	C [4]
Deschampsia flexuosa (sz)	Wavy hairgrass	P	C [4], [9]
Dicotyledonae (Adjacent forest edge)			
Achillea millefolium (sz)	Yarrow, Milfoil	P	C [4]
Alnus viridis (sf)	Alder	P	C [4]

Species	**Common Name**	**TG**	**C / I**
Alnus crispa (sf)		P	C [4]
Rubus chamaenorus		P	C [4]
Aster sp. (sf)	Aster	P	C [4], [9]
Arctium minus		P	C [4]
Empetrum nigrum (sf)	Black Crowberry	P	C [4]
Ligusticum scothicum	Scotch Lovage	P	C [4], [9]
Plantago maritima (sz)	Seaside Plantain	P	C [4], [9]
Rosa carolina (smf)	Rose	P	C [4], [9]
Solidago sempervirens (sz)	Seaside Goldenrod	P	C [4], [9]
Spiraea tomentosa (smf)	Steeplebush	P	C [4]
Vaccinium macrocarpon (smf)	Large Cranberry	P	C [4], [9]
Spermatophyta (Adjacent forest edge)			
Abies balsamea (smf)	Balsam Fir	P	C [4], [9]
Picea glauca (sf)	White Spruce	P	C [4], [9]
Cnidaria			
Dynamena (Sertularia) pumila (m on *Asco.*)	Sea oak	S	C [4], [5]
Nemertea			
Amphiporus ocraceus (l)	Amphiporus	C	C [4]
Tenuilineus (Lineus) bicolor (m)	Green gray lineus	C	C [4]
Lineus ruber (l)	Green/Red lineus	C	C [4]
Bryozoans			
Flustrellidra hispida (m on *Ascophyllum*)	Bristly bryozoan	S	I [8]
Mollusca			
Colisella (Acmaea) testudinalis (m-ll)	Tortoise-shell limpet	H	C[4], [5], [6]
Hydrobia minuta	Seaweed snail	H	
Tonicella (Ischnochiton) rubra (ll)	Northern red chiton	O	C[4]
Littorina littorea (m-l)	Common periwinkle	H	C [4], [6]
Littorina obtusata (m)	Smooth periwinkle	H	C[4]
Littorina saxatilis (sf)	Rough periwinkle	H	C[4]
Nucella (Thais) lapillas (m-ll)	Atlantic Dogwhelk	C	C [4], [6]
Lacuna vincta (l)	Northern/banded lacuna	H	C [4], [6]
Margarites groenlandica (ll)	Greenland margarite	H	C [4]
Modiolus modiolus (ll)	Horse mussel	S	I [10]
Mytilus edulis (m-ll)	Blue mussel	S	C [4]
Onchidoris bilamellata (ll)	Barnacle-eating onchidoris	C	I [4]
Skeneopsis planorbis (l-subtidal)	Flat skenea, orbsnail	H	C [4]
Annelida			
Potamilla neglecta (in crevices)	Tubicolous featherduster	S	I [8]
Fabricia sabella (m in crevices)	Featherduster/bristle worm	S	C [4]

Species	Common Name	TG	C / I
Spirorbis borealis	Sinistral spiral coiled worm	S	I [11]
Lepidonotus squamatus (l)	Twelve-scaled worm	C	C [4]
Naineris quadricuspida (l in crevice)	Polychaete	D	C [4]
Enchytraeus albidus (m on seaweed)	Pot worm	D	C [4]
Crustacea			
Semibalanus balanoides (m)	Northern rock barnacle	S	C [6]
Carcinus maenas (m-ll)	Green shore crab	C	I [11]
Gammarus oceanicus (u-ll)	Scud amphipod	H/O	C [7]
Jaera marina (m)	Little shore isopod	O?	C [4]
Idotea phosphorea (l)	Sharp-tail isopod	SC?	I [4]
Phidippus audax (sz)	Spider	C	C [4]
Echinodermata			
Strongylocentrotus drobachiensis (iz)	Green sea urchin	H/O	C [8]
Asterias rubens(vulgaris) (iz)	Northern sea star	C	I [11]
Asterias forbesi (iz)	Common sea star	C	I [11]
Psolus fabricii (iz)	Sea cucumber	S	C [4]
Mammalia			
Phoca vitulina	Harbour Seals	C	C [4]

Table A2.2. Species by Ecotype: Tidal Pools on Rocky Substratum (included in Fig. 2.3). C / I = Confirmed / Inferred, TG = Trophic group, P = primary producer, SC = scavenger, S = suspension feeder, D = deposit feeder, H = herbivore, C = carnivore, O = omnivore; u = upper midlittoral, m = midlittoral, l = low midlittoral; ll = low littoral; sf = supralittoral fringe; sz = supralittoral zone; smf = submaritime fringe; iz = infralittoral zone.

Species	Common Name	TG	C/I
Chlorophyta			
Entermorpha intestinalis (m)	Green alga	P	C [4]
Monostroma grevillei (m)	Sea lettuce	P	C [4]
Monostroma oxyspermum (m)	Sea lettuce	P	C [4]
Cladophora albida (m)		P	C [4]
Cladophora glaucescens (m)		P	C [4]
Cladophora rupestris (m)		P	C [4]
Chaetomorpha melagonium (m)	Green alga	P	C [4]
Chaetomorpha linum (m)	Green alga	P	C [4]
Spongomorpha arcta (m)		P	C [4]
Ulva lactuca (m)	Sea lettuce	P	C [4]
Urospora penicilliformis (m)	Sea lettuce	P	C [4]
Phaeophyta			
Alaria esculenta (m)	Kelp	P	C [4]
Asperococcus echinatus (l)		P	I [10]
Ectocarpus paradoxus (m)		P	C [4]
Ectocarpus tomentosus (m)		P	C [4]
Fucus distichus distichus (m)	Bladder wrack	P	C [4]

Species	**Common Name**	**TG**	**C/I**
Laminaria digitata (l)	Kelp	P	C [4]
Laminaria saccharina (l)	Kelp	P	C [4]
Petalonia fascia (m)		P	I [10]
Punctaria sp.		P	I [10]
Scytosiphon lomentaria (l)		P	I [10]
Rhodophyta			
Ceramium rubrum (m)		P	C [4]
Chondris crispus (l)	Irish moss	P	I [10]
Dumontia incrassata (D. contorta) (m)		P	C [4]
Hildenbrandia rubra (H. prototypus) (m)		P	I [10]
Lithothamnion glaciale (m)		P	C [5]
Mastocarpus stellatus (m)		P	I [10]
Phycodrys rubens (m)		P	C [4]
Phyllophora truncata (m)		P	C [4]
Phymatolithon lenormandii (m)		P	C [4]
Plumaria elegans (P. plumosa) (m)		P	C [4]
Polyides rotundus (m)		P	C [4]
Ptilota serrata (m)		P	C [4]
Rhodomela confervoides (m)		P	C [4]
Lichens			
Verrucaria sp.	Lichen	P	I [10]
Porifera			
Halichondria bowerbanki (m)	Crumb-of-bread	S	C [4]
Halichondria panicea (m)	Crumb-of-bread	S	C [4]
Haliclona loosanoffi (m)	Eroded sponge	S	C [4]
Haliclona oculata (m)	Finger or eyed sponge	S	C [4]
Cnidaria			
Aurelia aurita, ephyra (m)	Moon jelly, White jellyfish	C	C [4]
Bunodactis stella (m)	Green (Gem) anemone	S	C [4]
Metridium senile (m)	Plumose Anemone	S	C [4]
Schizotricha tenella (m)	Plumed hydroid	S	C [4]
Urticina (Tealia) felina (crassicornis) (m)	Dahlia anemone	S	C [4]
Ctenophora			
Pleurobrachia pileus (m)	Sea grape/walnut	C	C [4]
Plathyhelminthes			
Notoplana atomata (m)	Speckled flatworm	C	I [10]
Dalyelloida sp. (m)		C	C [4]
Nemertea			
Lineus ruber (m)	Green/Red lineus	C	I [10]
Tetrastemma candidum (m)	Green four-eyed ribbon worm	C	C [4]

Species	**Common Name**	**TG**	**C/I**
Bryozoa			
Electra pilosa (m on *Phyllophora*)	Encrusting bryozoan	S	C [4]
Crisiidae (m on *Ascophyllum)*	Jointed-tube bryozoan	S	C [4]
Annelida			
Potamilla neglecta (m)	Tubicolous featherduster	S	C [4]
Eulalia viridis	Paddleworm	C/S	C [4]
Flabelligera affinis	Polychaete	D	C [4]
Harmothoe imbricata (m)	Fifteen-scaled worm	C/O	C [4]
Spirorbis borealis (u)	Sinistral spiral coiled worm	S	C [4]
Mollusca			
Adalaria proxima (m)	Yellow false doris	C	C [4]
Aeolidia papillosa (m)	Shag-rug aeolis	C	C [4]
Anomia simplex (m)	Common smooth jingle	S	C [4]
Buccinum undatum (ll)	Waved whelk, buckie	C	C [4]
Colisella (Acmaea) testudinalis (m-ll)	Tortoise-shell limpet	H	C [4]
Crepidula fronicata (ll)	Atlantic slippersnail	S	I [4]
Dendronotus frondosus (l)	Frond-aeolis	C	C [4]
Hiatella arctica (m)	Arctic saxicave/hiatella	S	C [4]
Hydrobia minuta (H. totteni) (m)	Seaweed snail	H	C [4]
Littorina littorea (m)	Common periwinkle	H	C [4]
Littorina obtusata (m)	Smooth periwinkle	H	C [4]
Macoma balthica (m-l)	Little/baltic macoma	D	I [4]
Modiolus modiolus (ll)	Horse mussel	S	C [4]
Musculus discors (m)	Discordant mussel	S	C [4]
Mytilus edulis (m-l)	Blue mussel	S	I [4]
Nucella (Thias) lapillas (m-ll)	Atlantic dogwhelk	C	I [4]
Onchidoris muricata (aspersa) (m)	Fuzzy onchidoris	C	C [4]
Tonicella marmorea (ll)	Mottled red chiton	O	C [4]
Crustacea			
Semibalanus balanoides (m)	Northern rock barnacle	S	I [4]
Carcinus maenas (m-ll)	Green shore crab	C	I [10]
Gammarus oceanicus (u-l)	Scud amphipod	H/O	I [10]
Jaera marina (m)	Little shore isopod	O?	I [10]
Amphithoe rubricata (m)	Red-eyed amphipod	H	C [4]
Balanus crenatus (ll)	Crenate barnacle	S	C [4]
Gammarellus angulosus (m)	Amphipod	H/D	C [4]
Gammarellus homari (m)	Amphipod	H/D	C [4]
Halacarus sp. (u-m)	Mite	C?	C [4]
Pentaneura philippi (u)	Insect	C	C [4]
Orchestia gammarella (sf)	Beach flea	D?	C [4]
Orchestia grillus (u)	Beach flea	D?	C [4]
Echinodermata			
Asterias forbesi (m)	Common sea star	C	C [4]
Asterias rubens (vulgaris) (m)	Northern sea star	C	C [4]

Species	**Common Name**	**TG**	**C/I**
Cucumaria frondosa (ll)	Orange-footed sea cucumber	S	C [4]
Leptasterias littoralis (m)	Polar/green slender sea star	C	C [4]
Ophiopholis aculeata (m)	Daisy brittle star	D/C	C [4]
Urochordata			
Ascidia callosa (m)	Callused sea squirt	S	C [4]
Mogula citrina (m)	Orange sea grape	S	C [4]

Table A2.3. Species by Ecotype: Sand & Gravel Intertidal (Fig. 2.4).
C / I = Confirmed / Inferred, TG = Trophic group, P = primary producer, SC = scavenger, S = suspension feeder, D = deposit feeder, H = herbivore, C = carnivore, O = omnivore.

Species	**Common Name**	**TG**	**C/I**
Chlorophyta			
Zostera marina	Eelgrass	P	C [5]
Phaeophyta			
Fucus vesiculosus	Rockweed	P	C [7]
Ascophyllum nodosum	Knotted Wrack (Rockweed)	P	C [7]
Annelida			
Capitella capitata	Threadworm	D	C [4]
Clymenella torquata	Bambooworm worm	D	C [4], [5], [7]
Eteone sp. (m)	Paddleworm	C	C [4]
Glycera dibranchiata (m)	Two-gilled bloodworm	SC	C [4]
Nephthys incisa	Shimmyworm	D/C	I [12]
Nephthys picta (m)	Red-lined worm	C	C [4]
Nereis virens	Clam (rag) worm	H/O	I [12]
Lumbrinerides (Lumbrineris) acuta	Threadworm	C?	I [12]
Pectinaria (Cistenides) gouldi	Ice-cream-cone worm	D	I [12]
Scolecolepides viridis (m)	Red-gilled mudworm	D	C [4]
Mollusca			
Littorina littorea	Common periwinkle	H	C [7]
Littorina saxatilis	Rough periwinkle	H	C [7]
Euspira (Lunatia) heros	Northern moon snail	C	I [4], [12]
Nucella (Thais) lapillas	Atlantic Dogwhelk	C	C [7]
Buccinum undatum	Whelk	C	I [12]
Mya arenaria	Soft-shelled clam	S	I [12]
Ilyanassa (Nassarius) trivittatus (m)	Three-lined basketsnail	SC	C [4]
Crustacea			
Semibalanus balanoides	Northern rock barnacle	S	C [7]
Gammarus oceanicus	Amphipod	H/O	C [7]
Carcinus maenas	Green shore crab	C	C [7]
Chiridotea caeca	Burrowing isopod	SC?	C [4], [7]
Jaera marina	Little shore isopod	O?	I [12]

Echinodermata			
Echinarachnius parma	Sand dollar	D	I [12]
Strongylocentrotus drobachiensis	Green sea urchin	H/O	I [12]

Table A2.4. Species by Ecotype: Mudflat Intertidal (Fig. 2.5).
C / I = Confirmed / Inferred, TG = Trophic group, P = primary producer, SC = scavenger, S = suspension feeder, D = deposit feeder, H = herbivore, C = carnivore, O = omnivore.

Species	**Common Name**	**TG**	**C/I**
Chlorophyta			
Entermorpha intestinalis	Green alga	P	C [5], [7]
Ulva lactuca	Sea lettuce	P	C [7]
Zostera marina	Eelgrass	P	C [7]
Phaeophyta			
Fucus vesiculosus	Rockweed	P	C [7]
Rhodophyta			
Chondrus crispus	Irish moss	P	C [7]
Mastocarpus stellatus	Agar weed	P	C [7]
Annelida			
Arenicola marina	Lug worm		I [5]
Capitella capitata	Threadworm	D	C [4], [5], [7]
Clymenella torquata	Bambooworm	D	C [5], [7]
Fabricia sabella	Featherduster/bristle worm	S	C [13]
Hediste (Nereis) diversicolor	Ragworm	S/C	C [4]
Neoamphitrite (Amphitrite) johnstoni	Johnston ornate terebellid	D	C [7]
Nephthys incisa	Shimmyworm	D/C	C [7], [5]
Nereis pelagica	Pelagic clamworm	S/C	C [7]
Nereis virens	Clam (rag) worm	H/O	I [5],C [7]
Polycirrus eximius	Red terebellid	D	C [5], [7]
Streblospio benedicti	Bar-gill mudworm	D	C [13]
Mollusca			
Colisella (Acmaea) testudinalis	Tortoise-shell limpet	H	C [4], [7]
Littorea littorea	Common periwinkle	H	C [7]
Littorea saxatilis	Rough periwinkle	H	C [7]
Lunatia heros	Commom N. Moon-shell	C	C [7], [14]
Macoma balthica	Little/baltic macoma	D	C [7]
Mya arenaria	Soft-shelled clam	S	C [7]
Mytilus edulis	Blue mussel	S	C [7]
Nucella (Thais) lapillas	Atlantic Dogwhelk	C	C [6], [4], [7]
Crustacea			
Carcinus maenas	Green shore crab	C	C [7]
Chiridothea cacea	Burrowing isopod	SC?	I [5]
Corophium volutator	Tubicolous amphipod	D	C [4], [7], [13]

Species	Common Name	TG	C/I
Gammarus oceanicus	Amphipod	H/O	C [7]
Haustoriid amphipod	Sand burrowing Amphipod	S	I [5]
Hyale nilsoni	Amphipod	H	C [13]
Isopods	Isopods		C [7]
Semibalanus balanoides	Northern rock barnacle	S	C [7]
Nemertea			
Tenuilineus (Lineus) bicolor	Boot lace worm	C	C [4], C [7]
Lineus ruber	Green/Red lineus	C	C [4], C [7]
Procerodes littoralis (wheatlandi)	Orange reddish Flatworm	C	C [7]
Hemicordata			
Dilichlioglossus		D?	C [7]
Saccoglossus kowalewskii	Acorn Worm	D	C [7]

Table A2.5. Species by Ecotype: Salt Marsh (Fig. 2.6).

C / I = Confirmed / Inferred, TG = Trophic group, P = primary producer, SC = scavenger, S = suspension feeder, D = deposit feeder, H = herbivore, C = carnivore, O = omnivore; l = lowmarsh, h = highmarsh.

Species	Common Name	TG	C/I
Phaeophyta			
Ascophyllum nodosum f. scorpioides (l)	Low saltmarsh rockweed	P	C [4]
Monocotyledonae - Grasses			
Agropyron repens	Quackgrass	P	C [9]
Carex mackenziei	MacKenzie's sedge	P	C [9]
Carex palaecea	Sedge	P	C [9]
Cotula coronopifolia	Brass buttons	P	C [9]
Deschampsia flexuosa	Wavy hairgrass	P	C [9]
Eleocharis halophila	Saltmarsh spike-rush	P	C [9]
Hierochloa ordatata	Indian/vanilla/sweet grass	P	C [9]
Hordeum jubatum	Foxtail barley	P	C [9]
Juncus filiformis	Thread rush	P	C [5]
Juncus gerardi	Black grass	P	C [5], [9]
Phleum pratense	Timothy	P	C [9]
Scripus americanus	Bulrush	P	C [5]
Spartina alternifolia	Salt marsh cord grass	P	C [5]
Spartina patens	Salt marsh (meadow) hay	P	C [5]
Spartina pectinata	Slough grass	P	C [5]
Triglochin maritima	Arrow grass	P	C [9]
Dicotyledonae			
Aster borealis	Salt marsh aster	P	C [9]
Atriplex patula	Common orache	P	C [9]
Galium trifidum	Three-petalled bedstraw	P	C [9]
Glaux maritima	Sea milkwort	P	C [9]
Limonium nashi	Sea lavender	P	C [4], [5]
Plantago maritima	Seaside Plantain	P	C[4], [5], [9]

Species	Common Name	TG	C/I
Ranunculus cymbalaria	Seaside buttercup (Crowfoot)	P	C [9]
Salicornia europea	Glasswort, Samphire	P	C [5]
Solidago sempervirens	Salt marsh goldenrod	P	I [8]
Spermatophyta (Adjacent forest edge)			
Abies balsamea	Balsam Fir	P	C [4], [9]
Picea glauca	White Spruce	P	C [4], [9]
Annelida			
Hediste (Nereis) diversicolor	Ragworm	S/C	C [5]
Molluscs			
Littorina saxatilis	Rough periwinkle	H	C [5]
Macoma balthica	Little macoma	D	C [5]
Mytilus edulis	Blue mussel	S	C [5]

Table A2.6. Species by Ecotype: Pannes (included in Fig. 2.6).
C / I = Confirmed / Inferred, TG = Trophic group, P = primary producer, SC = scavenger, S = suspension feeder, D = deposit feeder, H = herbivore, C = carnivore, O = omnivore.

Species	Common Name	TG	C/I
Bacteria			
Pink bacteria	Pink bacteria		C [8]
Black bacteria	Black bacteria		C [8]
Chlorophyta			
Enteromorpha compressa	Green alga	P	C [4]
Rhizoclonium riparium		P	C [4]
Rhizoclonium tortuosum		P	C [4]
Monocotyledonae - Grasses			
Ruppia maritima	Widgeon grass	P	C [8]
Mollusca			
Litttorina saxatilis	Rough periwinkle	H	C [5]
Hydrobia minuta (H. totteni)	Seaweed snail	H	C [4], [5]
Crustacea			
Idotea phosphorea	Sharp-tail isopod	SC?	I [8]
Corophium volutator	Amphipod	D	I [8]
Gammarus mucronatus	Amphipod	DF?	I [8]
Hemicordata			
Alderia modesta	Salt marsh saccoglossan	D?	I [8]
Fishes			
Fundulus heteroclitus	Mummichog	C	C [8]

Gasterosteus aculeatus	Stickleback	C	C [8]

Table A2.7. Species by Ecotype: Subtidal mud and sand (included Fig. 2.7).
C / I = Confirmed / Inferred, TG = Trophic group, P = primary producer, SC = scavenger, S = suspension feeder, D = deposit feeder, H = herbivore, C = carnivore, O = omnivore.

Species	**Common Name**	**TG**	**C/I**
Nemertea			
Procerodes littoralis (wheatlandi)	Orange reddish Flatworm	C	I [12]
Annelida			
Aglaophamus neotena	Polychaete	C	C [13]
Brada villosa	Polychaete	D	C [15]
Clymenella torquata	Bambooworm	D	C [15]
Eteone longa	Paddleworm	C	C [13]
Goniada maculata	Chevronworm	C?	C [14], [15]
Hediste (Nereis) diversicolor	Ragworm	S/C	C [14]
Lumbrinerides (Lumbrineris) acuta	Threadworm	C?	I [12]
Nephthys cacea	Leafy shimmyworm	C	C [15]
Nephthys ciliata	Shimmyworm	C	C [15]
Nephthys incisa	Shimmyworm	D/C	C [14]
Nereis virens	Clam (rag) worm	H/O	C [15]
Ninoe nigripes	Threadworm	D/C	C [14]
Pectinaria (Cistenides) gouldi	Ice-cream-cone worm	D	C [15]
Phyllodoce mucosa	Paddleworm	C	C [15]
Polycirrus medusa	Terebellid worm	D	C [15]
Pygospio elegans	Mudworm	D/S	C [13]
Sternaspis scutata	Bristle worm	D	C [14]
Sthenelais limicola	Scaleworm	C	C [15]
Tubificoides (Peloscolex) benedeni	Sludge worm	D	C [13]
Chaetognatha			
Sagitta sp.	Arrow worm	C	C [13]
Cnidaria			
Edwardsia elegans?	Burrowing anemone	D?	C [15]
Crustacea			
Balanus crenatus	Crenate barnacle	S	C [15]
Cancer irroratus	Rock crab	C	I [12]
Carcinus maenas	Green shore crab	C	C [13]
Crangon septemspinosa	Sand shrimp	C	C [13], [14]
Edotea triloba (montosa)	Mound-back isopod	D/C	C [15]
Gammarus mucronatus	Amphipod	DF?	C [13]
Gammarus oceanicus	Amphipod	H/O	C [13]
Idotea phosphorea	Sharp-tail isopod	SC?	C [14]
Jaera marina	Little shore isopod	O?	C [13]
Leptocherius pinguis	Amphipod	D	C [14]
Mysis stenolepsis	Mysid shrimp	C	C [13]

Species	**Common Name**	**TG**	**C/I**
Neomysis americana	Mysid shrimp	C	C [13]
Oxyurostylis smithi	Cumacean shrimp	H/S	C [13]
Pseudoleptocuma (=Leptocuma) minor	Cumacean shrimp	H/S	C [13]
Mollusca			
Euspira (Lunatia) heros	Northern moon snail	C	C [14], [15]
Hydrobia minuta	Seaweed snail	H	C [13]
Littorina littorea	Common periwinkle	H	C [13]
Littorina saxatilis	Rough periwinkle	H	C [15]
Macoma balthica	Little macoma	D	C [15]
Mya arenaria	Soft-shelled clam	S	C [15]
Mytilus edulis	Blue mussel	S	C [15]
Nassarius trivittatus	Three-lined basketsnail	SC	C [14], [15]
Nucula delpdinodonta	Dolphintooth nutclam	S	C [14]
Placopectin magellanicus	Scallop	S	I [11]
Echinodermata			
Echinarachnius parma	Sand dollar	D	I [12]
Fishes			
Alosa aestivalis	Blueback herring	C	C [13]
Alosa pseudoharengus	Gaspereau/Alewife	C	C [13]
Alosa sapidissima	American Shad	C	C [13]
Angullia rostrata	Eel	SC	C [13]
Clupea harengus	Atlantic Herring	C	C [13]
Cyclopterus lumpus	Lumpfish	C	C [13]
Fundulus diaphanus	Banded killifish	C/O	C [13]
Fundulus heteroclitus	Mummichog/Chub	C/O	C [4], [13]
Gasterosteus aculeatus	Three-spined stickleback	C	C [4, 13]
Hemitripterus americanus	Sea raven	C	C [13]
Macrozoarces americanus	Wrymouth/Eel pout	C	C [13]
Menidia menidia	Atlantic silverside	C	C [13]
Microgadus tomcod	Atlantic tomcod/Frostfish	C	C [13]
Myoxocephalus scorpius	Shorthorn sculpin	C	C [4], [13]
Osmerus mordax	Rainbow smelt	C	C [13]
Pholis gunnellus	Rock eel/gunnel	C	C [4]
Pleuronectes (Limanda) ferrunginea	Yellowtail flounder	C	C [13]
Pleuronectes (Liopsetta) putnami	Smooth flounder	C	C [13]
Pollachius virens	Pollock	C	C [4], [13]
Pseudopleuronectes americanus	Winter Flounder	C	C [13]
Pungitius pungitius	Nine-spined stickleback	C	C [13]
Salvelinus fontinalis	Brook trout	C	C [13]
Urophycis chuss	Squirrel/Red hake	C	C [13]

Table A2.8. Species by Ecotype: Subtidal Rocky (hard bottom) - Musquash Head to Black Beach (included in Fig. 2.7).

C / I = Confirmed / Inferred, TG = Trophic group, P = primary producer, SC = scavenger, S = suspension feeder, D = deposit feeder, H = herbivore, C = carnivore, O = omnivore.

Species	**Common Name**	**TG**	**C/I**
Porifera			
Halichondria bowerbanki	Sponge	S	C [4]
Halichondria panicea	Sponge	S	C [4]
Haliclona loosanoffi	Sponge	S	C [4]
Haliclona oculata	Sponge	S	C [4]
Rhodophyta			
Laminaria digitata	Kelp	P	I [11]
Laminaria saccharina	Kelp	P	I [11]
Laminaria longicruris	Kelp	P	I [11]
Mollusca			
Mytilus edulis	Blue mussel	S	I [11]
Modiolus modiolus	Horse mussel	S	I [11]
Crustacea			
Balanus crenatus	Crenate barnacle	S	I [15]
Semibalanus balanoides	Northern rock barnacle	S	I [11]
Carcinus maenas	Green shore crab	C	I [11]
Gammarus oceanicus	Amphipod	H/O	I [11]
Homarus americanus	American lobster	C	I [11]
Echinodermata			
Strongylocentrotus drobachiensis	Green sea urchin	H/O	I [11]
Asterias vulgaris	Common Starfish	C	I [11]
Psolus fabricii	Sea cucumber	S	I [11]
Fishes			
Pseudopleuronectes americanus	Winter Flounder	C	I [11]
Pholis gunnellus	Rock eel	C	I [11]

Table A2.9. List of birds recorded in the area (see Fig. 2.8 for locations).

See map for recorded locations, All = throughout the area (* = recorded in 1999, r = rare; vr = very rare; vc = very common; n = nesting)

Species	**Common Name**	**Locations**	**C/I**
Squatarola(Pluvialis) squatarola	*Black-bellied plover	24, 28, 30	C [13], [16]
Totanus(Tringa) melanoleuca	*Greater yellowlegs	A, 7, 24	C [13], [16]
Erolia (Calidris) minutilla	*Least sandpiper	24	C [13], [16]
Crocethia alba	Sanderling	24, 28; (r)	C [13]
Charadris hiaticula semipalmatus	*Semipalmated plover	24	C [13], [16]
Ereunetes pusillus	*Semipalmated sandpiper	24, 28, 30	C [13], [16]
Limnodromus griseus	*Short-billed dowitcher	22, 23, 24	C [13],
Catoptrophorus semipalmatus	Willet	24; (r)	C [13]

Species	**Common Name**	**Locations**	**C/I**
Spizella arborea arborea	*Amer. (Eastern) Tree Sparrow	2, 9, 13	C [16]
Empidonax flaviventris	*Alder Flycatcher	4, 7, 35B	C [16]
Botaurus lentiginosus	*American Bittern	A, B, 1 (r)	C [16]
Anas rubripes	*American Black Duck	A, 7, 24 (n)	C [16]
Fulica americana	American Coot (Coot?)	A, B, C (r)	C [16]
Corvus brachyrhynchos?	*American Crow	All	C [16]
Carduelis flammea	*American Goldfinch	All	C [16]
Falco sparverius	American Kestrel	1, 4, 7 (n)	C [16]
Setophaga ruticilla	*American Redstart	All	C [16]
Turdus migratorius	*American Robin	All	C [16]
Mareca americana	*Amer. Widgeon (Baldpate?)	A, 2, 7	C [16]
Philohela minor	*American Woodcock	All	C [16]
Sterna paradisaea	Arctic Tern	38 (vr)	I [16]
Fratercula arctica arctica	Atlantic Puffin	38 (r)	I [16]
Erolia bairdii	Baird's Sandpiper	24 (r)	I [16]
Halioeetus leucocephalus	*Bald eagle	All	C [16]
Icterus galbula	Baltimore Oriole	4, 35A, 35B (vr)	I [16]
Riparia riparia riparia	*Bank Swallow	35B, A, 7	C [16]
Hirundo rustica erthrogaster	*Barn Swallow	4, 30, 35B	C [16]
Strix varia	*Barred Owl	13, 14, 16 (r)	C [16]
Dendroica castanea	Bay-breasted Warbler	E, F (r)	I [16]
Megaceryle alcyon alcyon	*Belted Kingfisher	8, 13, 19	C [16]
Mniotilta varia	*Black & White Warbler	All	C [16]
Cepphus grylle	*Black Guillemot	27, 29, 31 (n)	C [16]
Chlidonias nigra surinamensis	Black Tern	A?	I [16]
Picoides arcticus	Black-backed Woodpecker	F, 6, 30 (r)	I [16]
Coccyzus erthrophthalmus	Black-billed Cuckoo	35B	I [16]
Melanitta nigra	Black scoter	38	C [16]
Dendroica fusca	Black-burnian Warbler	E, F (r)	I [16]
Parus atricapillus	*Black-capped Chickadee	All	C [16]
Nycticorax nycticorax hoactli	Black-crowned Night Heron	C, 7, 8 (vr)	I [16]
Rissa tridactyla tridactyla	Black-legged Kittiwake	38 (r)	I [16]
Dendroica striata	Blackpoll Warbler	29, 30 (r)	I [16]
Dendroica coerulescens	Black-thr. Blue Warbler	F (vr)	I [16]
Dendroica virens	*Black-thr. Green Warbler	All	C [16]
Cyanocitta cristata	*Blue Jay	2, 6, 13	C [16]
Anas discors	*Blue-winged Teal	A,B (r)	C [16]
Dolichonyx oryzivorus	*Bobolink	A, B, C (r)	C [16]
Larus philadelphia	*Bonaparte's Gull	27, 29, 38 (r)	C [16]
Parus hudsonicus	*Boreal Chickadee	E, F, 30	C [16]
Branta bernicla	Brant	30, 36, 38 (r)	I [16]
Buteo platypterus platypterus	*Broad-winged Hawk	F, 7, 14 (n)	C [16]
Certhia familiaris	Brown Creeper	All (vr)	I [16]
Molothrus ater ater	*Brown-headed (Eastern?) Cowbird	4, 35A, 35B (r)	C [16]

Species	**Common Name**	**Locations**	**C/I**
Tryngites subruficollis	*Buff-breasted Sandpiper	B, 2 (vr)	C [16]
Glaucionetta albeola	Buffle-head	20, 21, A	C [16]
Branta canadensis	*Canada Goose	B, 2, 30 (n)	C [16]
Wilsonia canadensis	*Canada Warbler	8, 9, 14 (r)	C [16]
Dendroica tigrina	*Cape May Warbler	E, F (r)	C [16]
Hydroprogne caspia	Caspian Tern	38 (r)	I [16]
Bubulcus ibis	Cattle Egret	A, 7, 8 (vr)	
Bombycilla cedrorum	*Cedar Waxwing	All	C [16]
Dendroica pensylvanica	*Chestnut-sided Warbler	7, 8, 9	C [16]
Spizella passerina passerina	*(Eastern?) Chipping Sparrow	2, 4, 6	C [16]
Petrochelidon pyrrhonoto albifrons	*(Northern) Cliff Swallow	4, 6, 35B (r)	C [16]
Larus ridibundus ridibundus	Co. Black-headed Gull	24, 27,29 (vr)	C [16]
Somateria mollissima	*Common Eider	13, 21, 38 (n)	C [16]
Glaucionetta clangula americana?	*Common (Amer.) Golden-eye	A, 13, 21	C [16]
Quiscalis quiscula	*Common Grackle	All	C [16]
Gavia immer	*Common Loon	21, 30, 38	C [16]
Mergus merganser americanus	*(Amer.?) Common Merganser	13, 35A, 35B	C [16]
Gallinula chloropus	Common Moorhen	A (vr)	I [16]
Uria aagle aagle	Common Murre	38 (r)	I [16]
Chordeiles minor	*Common Nighthawk	1, 4, 24 (n)	C [16]
Corvus corax	*Common Raven	All	C [16]
Acanthis flammea	*Common Redpoll	All	C [16]
Capella gallinago	*Common Snipe	A, C, 7 (n)	C [16]
Sterna hirundo hirundo	*Common Tern	21, 27, 29 (r)	C [16]
Geothlypis trichas?	*Common Yellowthroat	A, 2, 14	C [16]
Junco hyemalis	*Dark-eyed (Northern) Junco	All	C [16]
Phalacrocorax auritus	*Double -crested Cormorant	13, 21, 38	C [16]
Plautus alle alle	Dovekie	38 (r)	I [16]
Dendrocopus borealis	*Downy Woodpecker	F, 2, 13	C [16]
Erolia alpina arctica	Dunlin	23, 24, 28	I [16]
Contopus virens	*E. Wood Pewee	F, 24	C [16]
Tyrannus tyrannus	*Eastern Kingbird	35A, 35B, 2	C [16]
Sturnella neglecta	Eastern Meadowlark	A, B, C (r)	I [16]
Sayornis phoebe	*Eastern Phoebe	27, 29	C [16]
Sturnus vulgaris vulgaris?	*European Starling	All (n)	C [16]
Hesperiphona vespertina	*Evening (Eastern?) Grosbeak	E, F, 35B	C [16]
Passerella iliaca iliaca	*(Eastern?) Fox Sparrow	E, 27, 29	C [16]
Anas strepera	Gadwall	A (r)	C [16]
Larus hyperboreus hyperboreus	Glaucous Gull	27, 29 (r)	C [16]
Regulus satrapa satrapa	*Golden-crowned Kinglet	E, F, 30	C [16]
Dumetella carolinensis?	*Gray Catbird	4, 28, 35B	C [16]
Perisoreus canadensis?	*(Canada?) Gray Jay	E, F, 30 (n)	C [16]

Species	**Common Name**	**Locations**	**C/I**
Hylocichla ustulata	Gray-cheeked Thrush	27, 29 (r)	I [16]
Larus marinus	*Great Black-backed Gull	All (n)	C [16]
Ardea herodias	*Great Blue Heron	All	C [16]
Phalacrocorax carbo carbo?	*Great Cormorant	38 (r)	C [16]
Myiarchus crinitus	Great Crested Flycatcher	4, 6	I [16]
Casmerodius albus	Great Egret	A, B, 7 (vr)	I [16]
Bubo virginianus	*Great Horned Owl	All (r)	C [16]
Aythya marila nearctica	*Greater Scaup	A, B, 21 (r)	C [16]
Puffinus lherminieri	Greater Shearwater	38?	I [16]
Butorides virescens virescens?	Green-backed Heron	A, 7, 8 (vr)	I [16]
Anas carolinensis	*Green-winged Teal	A, 2, 7	C [16]
Falco rusticolus obsoletus	*Gyrfalcon	All (vr)	C [16]
Dendrocopus villosus	*Hairy Woodpecker	F, 24, 30	C [16]
Histrionicus histrionicus	Harlequin Duck	38 (vr)	I [16]
Hylocichla guttata faxoni	*(Eastern) Hermit Thrush	E, F, 30	C [16]
Larus argentatus	*Herring Gull	All (n)	C [16]
Acanthis hornemanni exilipes	Hoary Redpoll	27, 29 (vr)	I [16]
Lophodytes cucullatus	*Hooded Merganser	A, C, 19 (r)	C [16]
Colymbus auritus	Horned Grebe	21, 31,38 (vr)	C [16]
Eremophilia alpestris	*Horned Lark	B, 2, 6	C [16]
Carpodacus mexicanus	House Finch	35B? (vr)	I [16]
Passer domesticus domesticus	House (English) Sparrow	35B (r)	I [16]
Limosa hoemastica	Hudsonian Godwit	30 (r)	I [16]
Larus leucopterus	*Iceland Gull	29 (r)	C [16]
Passerina cyanea	Indigo Bunting	35B (vr)	I [16]
Charadrius vociferus vociferus	*Killdeer	A, 28, 24	C [16]
Somateria spectabilis	King Eider	38 (vr)	I [16]
Calcarius lapponicus lapponicus	Lapland Longspur	4, 7 (vr)	I [16]
Larus atricilla	*Laughing Gull	21, 27, 28 (r)	C [16]
Oceanodroma leucorhoa leucorhoa	Leach's Storm Petrel	38?	I [16]
Empidonax minimus	*Least Flycatcher	4, 7	C [16]
Larus fuscus	Lesser Black-backed Gull	29 (vr)	I [16]
Pluvialis dominica	(Amer.?) Lesser Golden Plover	A, B, 7 (r)	I [16]
Aythya affinis	Lesser Scaup	21 (vr)	I [16]
Totanus flavipes	Lesser Yellowlegs	24, 30	I [16]
Melospiza lincolnii lincolnii	*Lincoln's Sparrow	1, 4, 7	C [16]
Larus minutus	Little Gull	38? (vr)	I [16]
Asio otus wilsonianus	Long-eared Owl	14,16, 20 (vr)	I [16]
Anas platyrhynchos platyrhynchos	*Mallard	A, 2, 7	C [16]
Dendroica magnolia	*Magnolia Warbler	All	C [16]
Cistothorus platensis stellaris?	(Short-billed?) Marsh Wren	A, B, C (vr)	I [16]
Falco columbarius	*Merlin	27, 29, 30	C [16]
Zenaidura macroura	*Mourning Dove	2, 35A, 35B (n)	I [16]
Oporornis philadelphia	*Mourning Warbler	F	C [16]

Species	**Common Name**	**Locations**	**C/I**
Vernivora ruficapilla ruficapilla	*Nashville Warbler	E, F	C [16]
Ammospiza caudacuta nelsoni	*Nelson's Sharp-tailed Sparrow	A, 2, 4	C [16]
Richmondena cardianlis	Nor. Cardinal	35B (r)	I [16]
Parula americana	*Nor. Parula (Warbler)	4, 18, 30	C [16]
Aegolius acadica acadica	Nor. Saw-whet Owl	F, 24, 30 (vr)	I [16]
Picoides tridactylus bacatus	Nor. Three-toed Woodpecker	30 (vr)	I [16]
Spatula clypeata	Northern Shoveller	A, B (vr)	I [16]
Colaptes auratus luteus	*Northern Flicker	All (vc)	C [16]
Fulmarus glacialis	Northern Fulmar	38?	I [16]
Morus bassanus	*Northern Gannet	31, 36, 38 (r)	C [16]
Accipiter gentilis atricapillus?	*Northern Goshawk	All (vr)	C [16]
Circus cyaneus hudsonius	*Northern Harrier	A, 4, 7 (r)	C [16]
Surnia ulula caparoch	Northern Hawk Owl	E, F (vr)	I [16]
Mimus polyglottus	Northern Mockingbird	35A,35B (vr)	I [16]
Anas acuta tzitzihoa?	*Northern Pintail	A, B, 7 (r)	C [16]
Lanius excubitor borealis	Northern Shrike	4, 28, 35B	C [16]
Seiurus noveboracensis noveboracensis	*Northern Waterthrush	8, 14, 19	C [16]
Clangula hyemalis	Oldsquaw	38	I [16]
Nuttallornis borealis	Olive-sided Flycatcher	6, 24, 30 (vr)	I [16]
Pnadion halioetus carolinensis	*Osprey	21, 29 (r)	C [16]
Seiurus aurocapillus	*Oven-bird	7, 9, 35B	C [16]
Dendroica palmarum	*Palm Warbler	4, 6, 7	C [16]
Erolia melanotos	Pectoral Sandpiper	4, 6, 24 (r)	I [16]
Falco peregrinus	*Peregrine Falcon	All	C [16]
Podilymbus podiceps podiceps	*Pied-billed Grebe	A, B, C (n)	C [16]
Hylatomus pileatus	Pileated Woodpecker	F, 24, 30 (r)	I [16]
Pinicola enucleator leucura	*(Canadian?) Pine Grosbeak	E, F, 24	C [16]
Spinus pinus pinus	*Pine Siskin	All	C [16]
Charadrius melodus	*Piping Plover	28 (vr)	C [16]
Carpodacus purpureus purpureus	*Purple Finch	E, F, 24	C [16]
Erolia maritima	*Purple Sandpiper	21, 27, 29	C [16]
Alca torda torda?	Razorbill (Razor-billed Auk?)	38 (r)	I [16]
Loxia curvirostra	Red Crossbill	E, F, 29 (r)	I [16]
Calidris canutus fufus	Red Knot	24, 28, 30 (r)	I [16]
Phalaropus fulicarius	Red Phalarope	38	I [16]
Mergus serrator	*Red-breasted Merganser	A, 13, 21 (n)	C [16]
Sitta canadensis	*Red-breasted Nuthatch	All (r)	C [16]
Vireo olivaceus	*Red-eyed Vireo	E, F, 9	C [16]
Colymbus grisegena holbolli?	Red-necked Grebe	38 (vr)	I [16]
Lobipes lobatus	Red-necked Phalarope (Northern)	21, 38	I [16]
Buteo jamaicensis	*Red-tailed Hawk	All (vr)	C [16]
Gavia stellata	*Red-throated Loon	27, 29, 38 (r)	C [16]
Agelaius phoeniceus?	*Red-winged Blackbird	A, B, C	C [16]

Species	**Common Name**	**Locations**	**C/I**
Larus delawarensis	*Ring-billed Gull	All	C [16]
Aythya collaris	*Ring-necked Duck	A, B, C	C [16]
Columba livia	*Rock Dove or Domestic Pigeon	4, 35A, 35B	C [16]
Sterna dougallii dougallii	Roseate Tern	38 (vr)	I [16]
Pheucticus ludovicianus	*Rose-breasted Grosbeak	2, 6, 35B	C [16]
Buteo lagopus s. johannis	*Rough-legged Hawk	A, B, 7	C [16]
Regulus calendula calendula	*Ruby-crowned Kinglet	All	C [16]
Archilochus colubris	*Ruby-throated Hummingbird	4, 35A, 35B (r)	C [16]
Erismatura jamaicensis rubida	Ruddy Duck	A? (vr)	I [16]
Arenaria interpres morinella	Ruddy Turnstone	30	I [16]
Bonasa umbellus	*Ruffled Grouse	All (n)	C [16]
Pipilo erythrophthalmus	Rufous-sided Towhee	35B (vr)	I [16]
Euphagus carolinus	*Rusty Blackbird	E, 7, 13 (r)	C [16]
Passerculus sandwichensis	*Savannah Sparrow	B, 4, 6	C [16]
Piranga olivacea	Scarlet Tanager	35B (vr)	I [16]
Troglodytes aedon?	Sedge (House?) Wren	A, B, C (vr)	I [16]
Accipiter straitus velox	*Sharp-shinned Hawk	All (n?)	C [16]
Asio flammeus flammeus	Short-eared Owl	B, 2, 7 (vr)	I [16]
Plectrophenax nivalis nivalis	*Snow Bunting	4, 7, 29	C [16]
Chen hyperborea	Snow Goose	A, B (r)	I [16]
Leucophoyx thula thula	Snowy Egret	A, B, 7 (vr)	I [16]
Nyctea scandiaca	Snowy Owl	B, 4, 7 (vr)	I [16]
Tringa solitaria solitaria	Solitary Sandpiper	4, 6	I [16]
Vireo solitarius	*Solitary (Blue-Headed?) Vireo	F, 18	C [16]
Melospiza melodia	*Song Sparrow	2, 7, 9	C [16]
Porzana carolina	*Sora	A, B, C	C [16]
Actitis macularia	*Spotted Sandpiper	13, 21, 24 (n)	C [16]
Canachites canadensis	*Spruce Grouse	E, F (n)	C [16]
Micropalama himantopus	*Stilt Sandpiper	4, 7, 24 (vr)	C [16]
Melanitta perspicillata	*Surf Scoter	21, 38	C [16]
Catharus guttatus	*Swainson's Thrush	E, 24, 30	C [16]
Melospiza georgiana	*Swamp Sparrow	E, 7, 9	C [16]
Vermivora peregrina	*Tennessee Warbler	E, F, 30	C [16]
Alca torda torda?	Thick-billed Murre	38 (vr)	I [16]
Iridoprocne bicolor	*Tree Swallow	All (n)	C [16]
Cathartes aura	Turkey Vulture	All (r)	I [16]
Bartramia longicauda	Upland Sandpiper	B (r)	I [16]
Hylocichla fuscescens	*Veery	1, 2, 35B	C [16]
Pooecetes gramineus gramineus	(Eastern?) Vesper Sparrow	2, 4, 6 (vr)	I [16]
Rallus limicola limicola	Virgina Rail	A?, B? (r)	I [16]
Anthus spinoletta rubescens?	*Water (American?) Pipit	2, 4, 6	C [16]
Ereunetes mauri	Western Sandpiper	24? (vr)	I [16]
Numenius arquata arquata	Whimbrel	B, 4, 6	I [16]
Zonotrichia leucophyrs	White-crowned Sparrow	27, 29	I [16]
Erolia fuscicollis	White-rumped Sandpiper	24	I [16]

Species	Common Name	Locations	C/I
Zonotrichia albicollis	*White-throated Sparrow	All	C [16]
Loxia leucoptera leucoptera	*White-winged Crossbill	All	C [16]
Steganopus tricolor	Wilson's Phalarope	A?, C?	I [16]
Wilsonia pusilla pusilla	*Wilson's Warbler	F, 8, 9 (r)	C [16]
Melanitta fusca deglandi	*(White?)-Winged Scoter	38	C [16]
Troglodytes troglodytes	*Winter Wren	All	C [16]
Aix sponsa	*Wood Duck	A, B, C	C [16]
Coturnicops noveboracensis noveboracensis	Yellow Rail	A?, B? (vr)	I [16]
Dendroica petechia	*Yellow Warbler	7, 13,35B (n)	C [16]
Empidonax flaviventris	*Yellow-bellied Flycatcher	F, 24, 30	C [16]
Dendroica coronata	*Yellow-rumped Warbler	All	C [16]

Table A2.10. The following table summarizes the number of rare, very rare and vagrant species of birds reported by Deichmann (1999) at various locations around the Estuary. See Fig. 2.8. for locations. [1].

Location number	Location name	Species	Location number	Location name	Species
39(A)	DU Impoundment (East)	29	22	Bents Beach	7
40(B)	DU Impoundment (West)	27	23	Camerons Beach	7
41(C)	DU Impoundment (Menzies)	14	24	Hepburn Basin	20
1	Board Bridge Creek	9	27	Western Head	15
2	Moose Creek	9	28	Black Beach	11
4	Devebers Point	18	29	Musquash Lighthouse	19
6	Menzies Manor	14	30	Gooseberry Cove	17
7	Dunns Creek	20	31	Gooseberry Island	9
8	Negro Brook	11	32	Little Musquash Cove	7
9	Perch Brook	9	33	Butlers Cove	7
13	Five Fathom Hole	9	34	White Rocks	7
14	Butlers Creek	11	35A	East Branch Musquash R.	9
16	Connors Cove	9	35B	West Branch Musquash R.	18
17	Wallace Cove	7	36	Split Rock	9
18	Cheeseman Beach	7	37	Coleson Cove	7
19	Frenchman & Burchill Brooks	8	38	Outer Estuary Offshore	28
20	Musquash Island	8	E (forest)	Along Musquash Lighthouse Rd.	14
21	Musquash Ledges	13	F (forest)	Along Gooseberry Cove Rd.	19

Table A2.11. List of birds recorded in the Ducks Unlimited Freshwater Impoundments located in the upper part of Musquash Estuary. The numbers at the bottom of the table indicate the total number of species recorded by Deichmann (1999) in each of the impoundments (s = spring, sum = summer, f = fall, w = winter).

Ducks Unlimited -A	**Ducks Unlimited -B**	**Ducks Unlimited -C**
American Crow	American Crow	American Crow
American Goldfinch	American Goldfinch	American Goldfinch
American Redstart	American Redstart	American Redstart
American Robin	American Robin	American Robin
American Woodcock	American Woodcock	American Woodcock
Bald Eagle	Bald Eagle	Bald Eagle
Black & White Warbler	Black & White Warbler	Black & White Warbler
Black -capped Chickadee	Black -capped Chickadee	Black -capped Chickadee
Black-thr. Green Warbler	Black-thr. Green Warbler	Black-thr. Green Warbler
Brown Creeper	Brown Creeper	Brown Creeper
Cedar Waxwing	Cedar Waxwing	Cedar Waxwing
Common Grackle	Common Grackle	Common Grackle
Common Raven	Common Raven	Common Raven
Common Redpoll	Common Redpoll	Common Redpoll
Dark-eyed Northern Junco	Dark-eyed Northern Junco	Dark-eyed Northern Junco
European Starling	European Starling	European Starling
Great Black-backed Gull	Great Black-backed Gull	Great Black-backed Gull
Great Blue Heron	Great Blue Heron	Great Blue Heron
Great Horned Owl	Great Horned Owl	Great Horned Owl
Gryfalcon	Gryfalcon	Gryfalcon
Herring Gull	Herring Gull	Herring Gull
Magnolia Warbler	Magnolia Warbler	Magnolia Warbler
Northern Flicker	Northern Flicker	Northern Flicker
Northern Goshawk	Northern Goshawk	Northern Goshawk
Peregrine Falcon	Peregrine Falcon	Peregrine Falcon
Pine Siskin	Pine Siskin	Pine Siskin
Red-breasted Nuthatch	Red-breasted Nuthatch	Red-breasted Nuthatch
Red-tailed Hawk	Red-tailed Hawk	Red-tailed Hawk
Ring-billed Gull	Ring-billed Gull	Ring-billed Gull
Ruby-crowned Kinglet	Ruby-crowned Kinglet	Ruby-crowned Kinglet
Ruffled Grouse	Ruffled Grouse	Ruffled Grouse
Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)
Tree Swallow (sum)	Tree Swallow (sum)	Tree Swallow (sum)
Turkey Vulture	Turkey Vulture	Turkey Vulture
White-throated Sparrow	White-throated Sparrow	White-throated Sparrow
White-winged Crossbill	White-winged Crossbill	White-winged Crossbill
Winter wren	Winter wren	Winter wren
Yellow-rumped Warbler	Yellow-rumped Warbler	Yellow-rumped Warbler
Greater Yellowlegs (s,f)	American Bittern	American Coot
American Bittern	American Coot	Black-crowned Night Heron
American Black Duck	Blue-winged Teal	Bobolink
American Coot	Bobolink	Common Snipe
American Widgeon	Buff-breasted Sandpiper	Eastern Meadowlark
Bank Swallow	Canada Goose	Hooded Merganser

Ducks Unlimited -A	**Ducks Unlimited -B**	**Ducks Unlimited -C**
Black Tern?	Eastern Meadowlark	Marsh Wren
Blue-winged Teal	Great Egret	Pied-billed Grebe
Bobolink	Greater Scaup (s,f)	Red-winged Blackbird
Bufflehead (s,f,w)	Horned Lark	Ring-necked Duck
Cattle Egret	Marsh Wren	Sedge (House) Wren
Common (American) Golden-eye (w)	Northern Shoveller	Sora
Common Moorhen	Northern Pintail	Wilson's Phalarope
Common Snipe	Pied-billed Grebe	Wood Duck
Common Yellowthroat	Red-winged Blackbird	
Eastern Meadowlark	Ring-necked Duck	
Gadwall	Rough-legged Hawk (s,f)	
Great Egret	Savannah Sparrow	
Greater Scaup (s,f)	Sedge (House) Wren	
Green-backed Heron	Short-eared Owl	
Green-winged Teal (s,f)	Snow Goose	
Hooded Merganser	Snowy Egret	
Killdeer (sum)	Snowy Owl	
(Amer.) Lesser Golden Plover (f)	Sora	
Mallard	Upland Sandpiper	
Marsh Wren	Virgina Rail?	
Nelson's Sharp-tailed Sparrow	Whimbrel	
Northern Shoveller	Wood Duck	
Northern Harrier (s,f)	Yellow Rail?	
Northern Pintail	(Amer.) Lesser Golden Plover (f)	
Pied-billed Grebe		
Red-breasted Merganser		
Red-winged Blackbird		
Ring-necked Duck		
Rough-legged Hawk (s,f)		
Ruddy Duck?		
Sedge (House) Wren		
Snow Goose		
Snowy Egret		
Sora		
Virgina Rail?		
Wilson's Phalarope		
Wood Duck		
Yellow Rail?		
82	**68**	**52**

Table A2.12. List of birds recorded in the adjacent forests along the Musquash Estuary. See map for locations. The numbers at the bottom of the table indicate the total number of species recorded by Deichmann (1999) in each of the two forests (s = spring, sum = summer, f = fall, w = winter).

E (South; Lighthouse Road forest)	**F (Gooseberry Cove Road forest)**
American Crow	American Crow
American Goldfinch	American Goldfinch
American Redstart	American Redstart
American Robin	American Robin
American Woodcock	American Woodcock
Bald Eagle	Bald Eagle
Black & White Warbler	Black & White Warbler
Black -capped Chickadee	Black -capped Chickadee
Black-thr. Green Warbler	Black-thr. Green Warbler
Brown Creeper	Brown Creeper
Cedar Waxwing	Cedar Waxwing
Common Grackle	Common Grackle
Common Raven	Common Raven
Common Redpoll	Common Redpoll
Dark-eyed Northern Junco	Dark-eyed Northern Junco
European Starling	European Starling
Great Black-backed Gull	Great Black-backed Gull
Great Blue Heron	Great Blue Heron
Great Horned Owl	Great Horned Owl
Gryfalcon	Gryfalcon
Herring Gull	Herring Gull
Magnolia Warbler	Magnolia Warbler
Northern Flicker	Northern Flicker
Northern Goshawk	Northern Goshawk
Peregrine Falcon	Peregrine Falcon
Pine Siskin	Pine Siskin
Red-breasted Nuthatch	Red-breasted Nuthatch
Red-tailed Hawk	Red-tailed Hawk
Ring-billed Gull	Ring-billed Gull
Ruby-crowned Kinglet	Ruby-crowned Kinglet
Ruffled Grouse	Ruffled Grouse
Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)
Tree Swallow (sum)	Tree Swallow (sum)
Turkey Vulture	Turkey Vulture
White-throated Sparrow	White-throated Sparrow
White-winged Crossbill	White-winged Crossbill
Winter wren	Winter wren
Yellow-rumped Warbler	Yellow-rumped Warbler
Bay-breasted Warbler	Bay-breasted Warbler
Black-burnian Warbler	Black-backed Woodpecker
Boreal Chickadee	Black-burnian Warbler
Cape May Warbler	Black-thr. Blue Warbler
Evening (Eastern) Grosbeak	Boreal Chickadee
Eastern Fox Sparrow (s,f)	Broad-winged Hawk (sum)

E (South; Lighthouse Road forest)	**F (Gooseberry Cove Road forest)**
Golden-crowned Kinglet	Cape May Warbler
Canada Gray Jay	Downy Woodpecker
Eastern Hermit Thrush	E. Wood Pwee
Nashville Warbler	Evening (Eastern) Grosbeak
Northern Hawk Owl	Golden-crowned Kinglet
Canadian Pine Grosbeak (w)	Canada Gray Jay
Purple Finch	Hairy Woodpecker
Red Crossbill	Eastern Hermit Thrush
Red-eyed Vireo	Mourning Warbler
Rusty Blackbird	Nashville Warbler
Spruce Grouse	Northern Saw-whet Owl
Swainson's Thrush	Northern Hawk Owl
Swamp Swallow	Pileated Woodpecker
Tennessee Warbler	Canadian Pine Grosbeak (w)
	Purple Finch
	Red Crossbill
	Red-eyed Vireo
	Solitary Vireo
	Spruce Grouse
	Tennessee Warbler
	Wilson's Warbler
	Yellow-bellied Flycatcher
58	**66**

Table A2.13. List of birds recorded in the area along the upper part of Musquash Estuary near Broad Bridge Creek, Moose (Roach's) Creek and Deveber Point. See map for locations. The numbers at the bottom of the table indicate the total number of species recorded by Deichmann (1999) in each of the locations (s = spring, sum = summer, f = fall, w = winter).

1 Broad Bridge Creek	**2 Moose (Roach's) Creek**	**4 Deveber Point**
American Crow	American Crow	American Crow
American Goldfinch	American Goldfinch	American Goldfinch
American Redstart	American Redstart	American Redstart
American Robin	American Robin	American Robin
American Woodcock	American Woodcock	American Woodcock
Bald Eagle	Bald Eagle	Bald Eagle
Black & White Warbler	Black & White Warbler	Black & White Warbler
Black -capped Chickadee	Black -capped Chickadee	Black -capped Chickadee
Black-thr. Green Warbler	Black-thr. Green Warbler	Black-thr. Green Warbler
Brown Creeper	Brown Creeper	Brown Creeper
Cedar Waxwing	Cedar Waxwing	Cedar Waxwing
Common Grackle	Common Grackle	Common Grackle
Common Raven	Common Raven	Common Raven
Common Redpoll	Common Redpoll	Common Redpoll
Dark-eyed Northern Junco	Dark-eyed Northern Junco	Dark-eyed Northern Junco
European Starling	European Starling	European Starling

1 Broad Bridge Creek	**2 Moose (Roach's) Creek**	**4 Deveber Point**
Great Black-backed Gull	Great Black-backed Gull	Great Black-backed Gull
Great Blue Heron	Great Blue Heron	Great Blue Heron
Great Horned Owl	Great Horned Owl	Great Horned Owl
Gryfalcon	Gryfalcon	Gryfalcon
Herring Gull	Herring Gull	Herring Gull
Magnolia Warbler	Magnolia Warbler	Magnolia Warbler
Northern Flicker	Northern Flicker	Northern Flicker
Northern Goshawk	Northern Goshawk	Northern Goshawk
Peregrine Falcon	Peregrine Falcon	Peregrine Falcon
Pine Siskin	Pine Siskin	Pine Siskin
Red-breasted Nuthatch	Red-breasted Nuthatch	Red-breasted Nuthatch
Red-tailed Hawk	Red-tailed Hawk	Red-tailed Hawk
Ring-billed Gull	Ring-billed Gull	Ring-billed Gull
Ruby-crowned Kinglet	Ruby-crowned Kinglet	Ruby-crowned Kinglet
Ruffled Grouse	Ruffled Grouse	Ruffled Grouse
Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)
Tree Swallow (sum)	Tree Swallow (sum)	Tree Swallow (sum)
Turkey Vulture	Turkey Vulture	Turkey Vulture
White-throated Sparrow	White-throated Sparrow	White-throated Sparrow
White-winged Crossbill	White-winged Crossbill	White-winged Crossbill
Winter wren	Winter wren	Winter wren
Yellow-rumped Warbler	Yellow-rumped Warbler	Yellow-rumped Warbler
American Bittern	Amer. (Eastern) Tree Sparrow (w)	Alder Flycatcher
American Kestrel (sum)	American Widgeon	American Kestrel (sum)
Common Nighthawk	Blue Jay	Baltimore Oriole
Lincoln's Sparrow	Buff-breasted Sandpiper	Barn Swallow (sum)
Veery	Canada Goose	Brown-headed (Eastern) Cowbird
	Eastern Chipping Sparrow	Eastern Chipping Sparrow
	Common Yellowthroat	Northern Cliff Swallow (sum)
	Downy Woodpecker	Common Nighthawk
	Eastern Kingbird	Gray Catbird
	Green-winged Teal (s,f)	Great crested Flycatcher
	Horned Lark	Lapland Longspur
	Mallard	Least Flycatcher
	Mourning Dove	Lincoln's Sparrow
	Nelson's Sharp-tailed Sparrow	Nelson's Sharp-tailed Sparrow
	Rose-breasted Grosbeak	Northern Parula (Warbler)
	Short-eared Owl	Northern Harrier (s,f)
	Song Sparrow	Northern Shrike (f,w)
	Veery	Palm Warbler
	Vesper Sparrow	Pectoral Sandpiper
	Water Pipit (s,f)	Domestic Pigeon
		Ruby-throated Hummingbird
		Savannah Sparrow
		Snow Bunting (w,s)
		Snowy Owl

1 Broad Bridge Creek	2 Moose (Roach's) Creek	4 Deveber Point
		Solitary Sandpiper (f)
		Stilt Sandpiper
		Vesper Sparrow
		Water Pipit (s,f)
		Whimbrel
43	58	67

Table A2.14. List of birds recorded in the area along the upper part of Musquash Estuary near Menzie's Manor, Dunn's, and Negro Brook. See map for locations. The numbers at the bottom of the table indicate the total number of species recorded by Deichmann (1999) in each of the locations (s = spring, sum = summer, f = fall, w = winter).

6 Menzie's Manor	**7 Dunn's**	**8 Negro Brook**
American Crow	American Crow	American Crow
American Goldfinch	American Goldfinch	American Goldfinch
American Redstart	American Redstart	American Redstart
American Robin	American Robin	American Robin
American Woodcock	American Woodcock	American Woodcock
Bald Eagle	Bald Eagle	Bald Eagle
Black & White Warbler	Black & White Warbler	Black & White Warbler
Black -capped Chickadee	Black -capped Chickadee	Black -capped Chickadee
Black-thr. Green Warbler	Black-thr. Green Warbler	Black-thr. Green Warbler
Brown Creeper	Brown Creeper	Brown Creeper
Cedar Waxwing	Cedar Waxwing	Cedar Waxwing
Common Grackle	Common Grackle	Common Grackle
Common Raven	Common Raven	Common Raven
Common Redpoll	Common Redpoll	Common Redpoll
Dark-eyed Northern Junco	Dark-eyed Northern Junco	Dark-eyed Northern Junco
European Starling	European Starling	European Starling
Great Black-backed Gull	Great Black-backed Gull	Great Black-backed Gull
Great Blue Heron	Great Blue Heron	Great Blue Heron
Great Horned Owl	Great Horned Owl	Great Horned Owl
Gryfalcon	Gryfalcon	Gryfalcon
Herring Gull	Herring Gull	Herring Gull
Magnolia Warbler	(Amer.) Lesser Golden Plover (f)	Magnolia Warbler
Northern Flicker	Magnolia Warbler	Northern Flicker
Northern Goshawk	Northern Flicker	Northern Goshawk
Peregrine Falcon	Northern Goshawk	Peregrine Falcon
Pine Siskin	Peregrine Falcon	Pine Siskin
Red-breasted Nuthatch	Pine Siskin	Red-breasted Nuthatch
Red-tailed Hawk	Red-breasted Nuthatch	Red-tailed Hawk
Ring-billed Gull	Red-tailed Hawk	Ring-billed Gull
Ruby-crowned Kinglet	Ring-billed Gull	Ruby-crowned Kinglet
Ruffled Grouse	Ruby-crowned Kinglet	Ruffled Grouse
Sharp-shinned Hawk (w)	Ruffled Grouse	Sharp-shinned Hawk (w)
Tree Swallow (sum)	Sharp-shinned Hawk (w)	Tree Swallow (sum)
Turkey Vulture	Tree Swallow (sum)	Turkey Vulture
White-throated Sparrow	Turkey Vulture	White-throated Sparrow
White-winged Crossbill	White-throated Sparrow	White-winged Crossbill
Winter wren	White-winged Crossbill	Winter wren
Yellow-rumped Warbler	Winter wren	Yellow-rumped Warbler
Black-backed Woodpecker	Yellow-rumped Warbler	Belted Kingfisher
Blue Jay	Greater Yellowlegs (s,f)	Black-crowned Night Heron
Eastern Chipping Sparrow	Alder Flycatcher	Canada Warbler
Northern Cliff Swallow (sum)	American Black Duck	Cattle Egret
Great crested Flycatcher	American Kestrel (sum)	Chestnut-sided Warbler

6 Menzie's Manor	7 Dunn's	8 Negro Brook
Horned Lark	American Widgeon	Green-backed Heron
Olive-sided Flycatcher	Bank Swallow	Northern Waterthrush
Palm Warbler	Black-crowned Night Heron	Wilson's Warbler
Pectoral Sandpiper	Broad-winged Hawk (sum)	
Rose-breasted Grosbeak	Cattle Egret	
Savannah Sparrow	Chestnut-sided Warbler	
Solitary Sandpiper (f)	Common Snipe	
Vesper Sparrow	Great Egret	
Water Pipit (s,f)	Green-backed Heron	
Whimbrel	Green-winged Teal (s,f)	
	Lapland Longspur	
	Least Flycatcher	
	Lincoln's Sparrow	
	Mallard	
	Northern Harrier (s,f)	
	Northern Pintail	
	Oven-bird	
	Palm Warbler	
	Rough-legged Hawk (s,f)	
	Rusty Blackbird	
	Short-eared Owl	
	Snow Bunting (w,s)	
	Snowy Egret	
	Snowy Owl	
	Song Sparrow	
	Stilt Sandpiper	
	Swamp Swallow	
	Yellow Warbler	
53	**71**	**46**

Table A2.15. List of birds recorded in the area along Musquash Estuary near Perch Brook, Five Fathom Hole Harbour and Butler Creek. See map for locations. The numbers at the bottom of the table indicate the total number of species recorded by Deichmann (1999) in each of the locations (s = spring, sum = summer, f = fall, w = winter).

9 Perch Brook	13 Five Fathom Hole Harbour	14 Butler Creek
American Crow	American Crow	American Crow
American Goldfinch	American Goldfinch	American Goldfinch
American Redstart	American Redstart	American Redstart
American Robin	American Robin	American Robin
American Woodcock	American Woodcock	American Woodcock
Bald Eagle	Bald Eagle	Bald Eagle
Black & White Warbler	Black & White Warbler	Black & White Warbler
Black -capped Chickadee	Black -capped Chickadee	Black -capped Chickadee
Black-thr. Green Warbler	Black-thr. Green Warbler	Black-thr. Green Warbler
Brown Creeper	Brown Creeper	Brown Creeper
Cedar Waxwing	Cedar Waxwing	Cedar Waxwing

9 Perch Brook	**13 Five Fathom Hole Harbour**	**14 Butler Creek**
Common Grackle	Common Grackle	Common Grackle
Common Raven	Common Raven	Common Raven
Common Redpoll	Common Redpoll	Common Redpoll
Dark-eyed Northern Junco	Dark-eyed Northern Junco	Dark-eyed Northern Junco
European Starling	European Starling	European Starling
Great Black-backed Gull	Great Black-backed Gull	Great Black-backed Gull
Great Blue Heron	Great Blue Heron	Great Blue Heron
Great Horned Owl	Great Horned Owl	Great Horned Owl
Gryfalcon	Gryfalcon	Gryfalcon
Herring Gull	Herring Gull	Herring Gull
Magnolia Warbler	Magnolia Warbler	Magnolia Warbler
Northern Flicker	Northern Flicker	Northern Flicker
Northern Goshawk	Northern Goshawk	Northern Goshawk
Peregrine Falcon	Peregrine Falcon	Peregrine Falcon
Pine Siskin	Pine Siskin	Pine Siskin
Red-breasted Nuthatch	Red-breasted Nuthatch	Red-breasted Nuthatch
Red-tailed Hawk	Red-tailed Hawk	Red-tailed Hawk
Ring-billed Gull	Ring-billed Gull	Ring-billed Gull
Ruby-crowned Kinglet	Ruby-crowned Kinglet	Ruby-crowned Kinglet
Ruffled Grouse	Ruffled Grouse	Ruffled Grouse
Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)
Tree Swallow (sum)	Tree Swallow (sum)	Tree Swallow (sum)
Turkey Vulture	Turkey Vulture	Turkey Vulture
White-throated Sparrow	White-throated Sparrow	White-throated Sparrow
White-winged Crossbill	White-winged Crossbill	White-winged Crossbill
Winter wren	Winter wren	Winter wren
Yellow-rumped Warbler	Yellow-rumped Warbler	Yellow-rumped Warbler
Amer. (Eastern) Tree Sparrow (w)	Amer. (Eastern) Tree Sparrow (w)	Barred Owl
Canada Warbler	Barred Owl	Broad-winged Hawk (sum)
Chestnut-sided Warbler	Belted Kingfisher	Canada Warbler
Oven-bird	Blue Jay	Common Yellowthroat
Red-eyed Vireo	Common Eider	Long-eared Owl
Song Sparrow	Common (Amer.) Golden-eye (w)	Northern Waterthrush
Swamp Swallow	Commom (American) Merganser	
Wilson's Warbler	Double-crested Cormorant	
	Downy Woodpecker	
	Red-breasted Merganser	
	Rusty Blackbird	
	Spotted Sandpiper (sum)	
	Yellow Warbler	
46	**51**	**44**

Table A2.16. List of birds recorded in the area along Musquash Estuary near Connors Creek, Wallace Cove and Cheeseman Beach. See map for locations. The numbers at the bottom of the table indicate the total number of species recorded by Deichmann (1999) in each of the locations (s = spring, sum = summer, f = fall, w = winter).

16 Connor Creek	**17 Wallace Cove**	**18 Cheeseman Beach**
American Crow	American Crow	American Crow
American Goldfinch	American Goldfinch	American Goldfinch
American Redstart	American Redstart	American Redstart
American Robin	American Robin	American Robin
American Woodcock	American Woodcock	American Woodcock
Bald Eagle	Bald Eagle	Bald Eagle
Black & White Warbler	Black & White Warbler	Black & White Warbler
Black -capped Chickadee	Black -capped Chickadee	Black -capped Chickadee
Black-thr. Green Warbler	Black-thr. Green Warbler	Black-thr. Green Warbler
Brown Creeper	Brown Creeper	Brown Creeper
Cedar Waxwing	Cedar Waxwing	Cedar Waxwing
Common Grackle	Common Grackle	Common Grackle
Common Raven	Common Raven	Common Raven
Common Redpoll	Common Redpoll	Common Redpoll
Dark-eyed Northern Junco	Dark-eyed Northern Junco	Dark-eyed Northern Junco
European Starling	European Starling	European Starling
Great Black-backed Gull	Great Black-backed Gull	Great Black-backed Gull
Great Blue Heron	Great Blue Heron	Great Blue Heron
Great Horned Owl	Great Horned Owl	Great Horned Owl
Gryfalcon	Gryfalcon	Gryfalcon
Herring Gull	Herring Gull	Herring Gull
Magnolia Warbler	Magnolia Warbler	Magnolia Warbler
Northern Flicker	Northern Flicker	Northern Flicker
Northern Goshawk	Northern Goshawk	Northern Goshawk
Peregrine Falcon	Peregrine Falcon	Peregrine Falcon
Pine Siskin	Pine Siskin	Pine Siskin
Red-breasted Nuthatch	Red-breasted Nuthatch	Red-breasted Nuthatch
Red-tailed Hawk	Red-tailed Hawk	Red-tailed Hawk
Ring-billed Gull	Ring-billed Gull	Ring-billed Gull
Ruby-crowned Kinglet	Ruby-crowned Kinglet	Ruby-crowned Kinglet
Ruffled Grouse	Ruffled Grouse	Ruffled Grouse
Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)
Tree Swallow (sum)	Tree Swallow (sum)	Tree Swallow (sum)
Turkey Vulture	Turkey Vulture	Turkey Vulture
White-throated Sparrow	White-throated Sparrow	White-throated Sparrow
White-winged Crossbill	White-winged Crossbill	White-winged Crossbill
Winter wren	Winter wren	Winter wren
Yellow-rumped Warbler	Yellow-rumped Warbler	Yellow-rumped Warbler
Barred Owl		Northern Parula (Warbler)
Long-eared Owl		Solitary Vireo
40	**38**	**40**

Table A2.17. List of birds recorded in the area along the outer Musquash Estuary near Frenchman & Birchill Brook, Musquash Island and Musquash Ledges. See map for locations. The numbers at the bottom of the table indicate the total number of species recorded by Deichmann (1999) in each of the locations (s = spring, sum = summer, f = fall, w = winter).

19 Frenchman & Burchill Brook	**20 Musquash Island**	**21 Musquash Ledges**
American Crow	American Crow	American Crow
American Goldfinch	American Goldfinch	American Goldfinch
American Redstart	American Redstart	American Redstart
American Robin	American Robin	American Robin
American Woodcock	American Woodcock	American Woodcock
Bald Eagle	Bald Eagle	Bald Eagle
Black & White Warbler	Black & White Warbler	Black & White Warbler
Black -capped Chickadee	Black -capped Chickadee	Black -capped Chickadee
Black-thr. Green Warbler	Black-thr. Green Warbler	Black-thr. Green Warbler
Brown Creeper	Brown Creeper	Brown Creeper
Cedar Waxwing	Cedar Waxwing	Cedar Waxwing
Common Grackle	Common Grackle	Common Grackle
Common Raven	Common Raven	Common Raven
Common Redpoll	Common Redpoll	Common Redpoll
Dark-eyed Northern Junco	Dark-eyed Northern Junco	Dark-eyed Northern Junco
European Starling	European Starling	European Starling
Great Black-backed Gull	Great Black-backed Gull	Great Black-backed Gull
Great Blue Heron	Great Blue Heron	Great Blue Heron
Great Horned Owl	Great Horned Owl	Great Horned Owl
Gryfalcon	Gryfalcon	Gryfalcon
Herring Gull	Herring Gull	Herring Gull
Magnolia Warbler	Magnolia Warbler	Magnolia Warbler
Northern Flicker	Northern Flicker	Northern Flicker
Northern Goshawk	Northern Goshawk	Northern Goshawk
Peregrine Falcon	Peregrine Falcon	Peregrine Falcon
Pine Siskin	Pine Siskin	Pine Siskin
Red-breasted Nuthatch	Red-breasted Nuthatch	Red-breasted Nuthatch
Red-tailed Hawk	Red-tailed Hawk	Red-tailed Hawk
Ring-billed Gull	Ring-billed Gull	Ring-billed Gull
Ruby-crowned Kinglet	Ruby-crowned Kinglet	Ruby-crowned Kinglet
Ruffled Grouse	Ruffled Grouse	Ruffled Grouse
Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)
Tree Swallow (sum)	Tree Swallow (sum)	Tree Swallow (sum)
Turkey Vulture	Turkey Vulture	Turkey Vulture
White-throated Sparrow	White-throated Sparrow	White-throated Sparrow
White-winged Crossbill	White-winged Crossbill	White-winged Crossbill
Winter wren	Winter wren	Winter wren
Yellow-rumped Warbler	Yellow-rumped Warbler	Yellow-rumped Warbler
Belted Kingfisher	Bufflehead (s,f,w)	Bufflehead (s,f,w)
Hooded Merganser	Long-eared Owl	Common Eider
Northern Waterthrush		Common (Amer.) Golden-eye (w)
		Common Loon

19 Frenchman & Burchill Brook	20 Musquash Island	21 Musquash Ledges
		Common Tern
		Double-crested Cormorant
		Greater Scaup (s,f)
		Horned Grebe
		Laughing Gull
		Lesser Scaup
		Osprey (sum)
		Purple Sandpiper (w)
		Red-breasted Merganser
		Red-necked Phalarope
		Spotted Sandpiper (sum)
		Surf Scoter (sum)
41	40	54

Table A2.18. List of birds recorded in the area along the outer Musquash Estuary near Bent Beach, Cameron Beach and Hepburn Basin. See map for locations. The numbers at the bottom of the table indicate the total number of species recorded by Deichmann (1999) in each of the locations (s = spring, sum = summer, f = fall, w = winter).

22 Bent Beach	23 Cameron Beach	24 Hepburn Basin
American Crow	American Crow	American Crow
American Goldfinch	American Goldfinch	American Goldfinch
American Redstart	American Redstart	American Redstart
American Robin	American Robin	American Robin
American Woodcock	American Woodcock	American Woodcock
Bald Eagle	Bald Eagle	Bald Eagle
Black & White Warbler	Black & White Warbler	Black & White Warbler
Black -capped Chickadee	Black -capped Chickadee	Black -capped Chickadee
Black-thr. Green Warbler	Black-thr. Green Warbler	Black-thr. Green Warbler
Brown Creeper	Brown Creeper	Brown Creeper
Cedar Waxwing	Cedar Waxwing	Cedar Waxwing
Common Grackle	Common Grackle	Common Grackle
Common Raven	Common Raven	Common Raven
Common Redpoll	Common Redpoll	Common Redpoll
Dark-eyed Northern Junco	Dark-eyed Northern Junco	Dark-eyed Northern Junco
European Starling	European Starling	European Starling
Great Black-backed Gull	Great Black-backed Gull	Great Black-backed Gull
Great Blue Heron	Great Blue Heron	Great Blue Heron
Great Horned Owl	Great Horned Owl	Great Horned Owl
Gryfalcon	Gryfalcon	Gryfalcon
Herring Gull	Herring Gull	Herring Gull
Magnolia Warbler	Magnolia Warbler	Magnolia Warbler
Northern Flicker	Northern Flicker	Northern Flicker
Northern Goshawk	Northern Goshawk	Northern Goshawk
Peregrine Falcon	Peregrine Falcon	Peregrine Falcon
Pine Siskin	Pine Siskin	Pine Siskin
Red-breasted Nuthatch	Red-breasted Nuthatch	Red-breasted Nuthatch

22 Bent Beach	**23 Cameron Beach**	**24 Hepburn Basin**
Red-tailed Hawk	Red-tailed Hawk	Red-tailed Hawk
Ring-billed Gull	Ring-billed Gull	Ring-billed Gull
Ruby-crowned Kinglet	Ruby-crowned Kinglet	Ruby-crowned Kinglet
Ruffled Grouse	Ruffled Grouse	Ruffled Grouse
Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)
Tree Swallow (sum)	Tree Swallow (sum)	Tree Swallow (sum)
Turkey Vulture	Turkey Vulture	Turkey Vulture
White-throated Sparrow	White-throated Sparrow	White-throated Sparrow
White-winged Crossbill	White-winged Crossbill	White-winged Crossbill
Winter wren	Winter wren	Winter wren
Yellow-rumped Warbler	Yellow-rumped Warbler	Yellow-rumped Warbler
Shortbilled dowitcher (f)	Shortbilled dowitcher (f)	Black-bellied Plover (f)
	Dunlin	Greater Yellowlegs (s,f)
		Least sandpiper (f)
		Sanderling
		Semipalmated plover (f)
		Semipalmated sandpiper (s,f)
		Shortbilled dowitcher (f)
		Willet (f)
		American Black Duck
		Baird's Sandpiper
		Common Black-headed Gull
		Common Nighthawk
		Dunlin
		E. Wood Pwee
		Hairy Woodpecker
		Killdeer (sum)
		Lesser Yellowlegs (f)
		Northern Saw-whet Owl
		Olive-sided Flycatcher
		Pectoral Sandpiper
		Pileated Woodpecker
		Canadian Pine Grosbeak (w)
		Purple Finch
		Red Knot
		Spotted Sandpiper (sum)
		Stilt Sandpiper
		Swainson's Thrush
		Western Sandpiper
		White-rumped Sandpiper (f)
		Yellow-bellied Flycatcher
39	**40**	**68**

Table A2.19. List of birds recorded in the area along the outer Musquash Estuary near Western Head, Black Beach and South Musquash Light. See map for locations. The numbers at the bottom of the table indicate the total number of species recorded by Deichmann (1999) in each of the locations (s = spring, sum = summer, f = fall, w = winter).

27 Western Head	**28 Black Beach**	**29 South Mucquash Light**
American Crow	American Crow	American Crow
American Goldfinch	American Goldfinch	American Goldfinch
American Redstart	American Redstart	American Redstart
American Robin	American Robin	American Robin
American Woodcock	American Woodcock	American Woodcock
Bald Eagle	Bald Eagle	Bald Eagle
Black & White Warbler	Black & White Warbler	Black & White Warbler
Black -capped Chickadee	Black -capped Chickadee	Black -capped Chickadee
Black-thr. Green Warbler	Black-thr. Green Warbler	Black-thr. Green Warbler
Brown Creeper	Brown Creeper	Brown Creeper
Cedar Waxwing	Cedar Waxwing	Cedar Waxwing
Common Grackle	Common Grackle	Common Grackle
Common Raven	Common Raven	Common Raven
Common Redpoll	Common Redpoll	Common Redpoll
Dark-eyed Northern Junco	Dark-eyed Northern Junco	Dark-eyed Northern Junco
European Starling	European Starling	European Starling
Great Black-backed Gull	Great Black-backed Gull	Great Black-backed Gull
Great Blue Heron	Great Blue Heron	Great Blue Heron
Great Horned Owl	Great Horned Owl	Great Horned Owl
Gryfalcon	Gryfalcon	Gryfalcon
Herring Gull	Herring Gull	Herring Gull
Magnolia Warbler	Magnolia Warbler	Magnolia Warbler
Northern Flicker	Northern Flicker	Northern Flicker
Northern Goshawk	Northern Goshawk	Northern Goshawk
Peregrine Falcon	Peregrine Falcon	Peregrine Falcon
Pine Siskin	Pine Siskin	Pine Siskin
Red-breasted Nuthatch	Red-breasted Nuthatch	Red-breasted Nuthatch
Red-tailed Hawk	Red-tailed Hawk	Red-tailed Hawk
Ring-billed Gull	Ring-billed Gull	Ring-billed Gull
Ruby-crowned Kinglet	Ruby-crowned Kinglet	Ruby-crowned Kinglet
Ruffled Grouse	Ruffled Grouse	Ruffled Grouse
Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)
Tree Swallow (sum)	Tree Swallow (sum)	Tree Swallow (sum)
Turkey Vulture	Turkey Vulture	Turkey Vulture
White-throated Sparrow	White-throated Sparrow	White-throated Sparrow
White-winged Crossbill	White-winged Crossbill	White-winged Crossbill
Winter wren	Winter wren	Winter wren
Yellow-rumped Warbler	Yellow-rumped Warbler	Yellow-rumped Warbler
Black Guillemot	Black-bellied Plover (f)	Black Guillemot
Bonaparte's Gull	Sanderling	Blackpoll Warbler
Common Black-headed Gull	Semipalmated sandpiper (s,f)	Bonaparte's Gull
Common Tern	Dunlin	Common Black-headed Gull

27 Western Head	28 Black Beach	29 South Mucquash Light
Eastern Phoebe	Gray Catbird	Common Tern
Eastern Fox Sparrow (s,f)	Killdeer (sum)	Eastern Phoebe
Glaucous Gull	Laughing Gull	Eastern Fox Sparrow (s,f)
Gray-cheeked Thrush	Northern Shrike (f,w)	Glaucous Gull
Hoary Redpoll	Piping Plover (f)	Gray-cheeked Thrush
Laughing Gull	Red Knot	Hoary Redpoll
Merlin		Iceland Gull (w,s)
Purple Sandpiper (w)		Lesser Black-backed Gull
Red-throated Loon		Merlin
White-crowned Sparrow (s,f)		Osprey (sum)
		Purple Sandpiper (w)
		Red Crossbill
		Red-throated Loon
		Snow Bunting (w,s)
		White-crowned Sparrow (s,f)
52	**48**	**57**

Table A2.20. List of birds recorded in the area along the outer Musquash Estuary near Gooseberry Cove, Gooseberry Island and Butler Cove. See map for locations. The numbers at the bottom of the table indicate the total number of species recorded by Deichmann (1999) in each of the locations (s = spring, sum = summer, f = fall, w = winter).

30 Gooseberry Cove	31 Gooseberry Island	33 Butler Cove
American Crow	American Crow	American Crow
American Goldfinch	American Goldfinch	American Goldfinch
American Redstart	American Redstart	American Redstart
American Robin	American Robin	American Robin
American Woodcock	American Woodcock	American Woodcock
Bald Eagle	Bald Eagle	Bald Eagle
Black & White Warbler	Black & White Warbler	Black & White Warbler
Black -capped Chickadee	Black -capped Chickadee	Black -capped Chickadee
Black-thr. Green Warbler	Black-thr. Green Warbler	Black-thr. Green Warbler
Brown Creeper	Brown Creeper	Brown Creeper
Cedar Waxwing	Cedar Waxwing	Cedar Waxwing
Common Grackle	Common Grackle	Common Grackle
Common Raven	Common Raven	Common Raven
Common Redpoll	Common Redpoll	Common Redpoll
Dark-eyed Northern Junco	Dark-eyed Northern Junco	Dark-eyed Northern Junco
European Starling	European Starling	European Starling
Great Black-backed Gull	Great Black-backed Gull	Great Black-backed Gull
Great Blue Heron	Great Blue Heron	Great Blue Heron
Great Horned Owl	Great Horned Owl	Great Horned Owl
Gryfalcon	Gryfalcon	Gryfalcon
Herring Gull	Herring Gull	Herring Gull
Magnolia Warbler	Magnolia Warbler	Magnolia Warbler
Northern Flicker	Northern Flicker	Northern Flicker

30 Gooseberry Cove	**31 Gooseberry Island**	**33 Butler Cove**
Northern Goshawk	Northern Goshawk	Northern Goshawk
Peregrine Falcon	Peregrine Falcon	Peregrine Falcon
Pine Siskin	Pine Siskin	Pine Siskin
Red-breasted Nuthatch	Red-breasted Nuthatch	Red-breasted Nuthatch
Red-tailed Hawk	Red-tailed Hawk	Red-tailed Hawk
Ring-billed Gull	Ring-billed Gull	Ring-billed Gull
Ruby-crowned Kinglet	Ruby-crowned Kinglet	Ruby-crowned Kinglet
Ruffled Grouse	Ruffled Grouse	Ruffled Grouse
Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)
Tree Swallow (sum)	Tree Swallow (sum)	Tree Swallow (sum)
Turkey Vulture	Turkey Vulture	Turkey Vulture
White-throated Sparrow	White-throated Sparrow	White-throated Sparrow
White-winged Crossbill	White-winged Crossbill	White-winged Crossbill
Winter wren	Winter wren	Winter wren
Yellow-rumped Warbler	Yellow-rumped Warbler	Yellow-rumped Warbler
Black-bellied Plover (f)	Black Guillemot	
Semipalmated sandpiper(s,f)	Horned Grebe	
Barn Swallow (sum)	Northern Gannet	
Black-backed Woodpecker		
Blackpoll Warbler		
Boreal Chickadee		
Brant (s)		
Canada Goose		
Common Loon		
Golden-crowned Kinglet		
Canada Gray Jay		
Hairy Woodpecker		
Eastern Hermit Thrush		
Hudsonian Godwit		
Lesser Yellowlegs (f)		
Merlin		
Northern Parula (Warbler)		
Northern Saw-whet Owl		
Northern Three-toed Woodpecker		
Olive-sided Flycatcher		
Pileated Woodpecker		
Red Knot		
Ruddy Turnstone		
Swainson's Thrush		
Tennessee Warbler		
Yellow-bellied Flycatcher		
64	**41**	**38**

Table A2.21. List of birds recorded in the area along the outer Musquash Estuary near White Rocks and along the inner estuary near the head of the tide at the East and West Branches of the Musquash River. See map for locations. The numbers at the bottom of the table indicate the total number of species recorded by Deichmann (1999) in each of the locations (s = spring, sum = summer, f = fall, w = winter).

34 White Rocks	**35A. E. Br. Musq. River**	**35B. W. Br. Musq. River**
American Crow	American Crow	American Crow
American Goldfinch	American Goldfinch	American Goldfinch
American Redstart	American Redstart	American Redstart
American Robin	American Robin	American Robin
American Woodcock	American Woodcock	American Woodcock
Bald Eagle	Bald Eagle	Bald Eagle
Black & White Warbler	Black & White Warbler	Black & White Warbler
Black -capped Chickadee	Black -capped Chickadee	Black -capped Chickadee
Black-thr. Green Warbler	Black-thr. Green Warbler	Black-thr. Green Warbler
Brown Creeper	Brown Creeper	Brown Creeper
Cedar Waxwing	Cedar Waxwing	Cedar Waxwing
Common Grackle	Common Grackle	Common Grackle
Common Raven	Common Raven	Common Raven
Common Redpoll	Common Redpoll	Common Redpoll
Dark-eyed Northern Junco	Dark-eyed Northern Junco	Dark-eyed Northern Junco
European Starling	European Starling	European Starling
Great Black-backed Gull	Great Black-backed Gull	Great Black-backed Gull
Great Blue Heron	Great Blue Heron	Great Blue Heron
Great Horned Owl	Great Horned Owl	Great Horned Owl
Gryfalcon	Gryfalcon	Gryfalcon
Herring Gull	Herring Gull	Herring Gull
Magnolia Warbler	Magnolia Warbler	Magnolia Warbler
Northern Flicker	Northern Flicker	Northern Flicker
Northern Goshawk	Northern Goshawk	Northern Goshawk
Peregrine Falcon	Peregrine Falcon	Peregrine Falcon
Pine Siskin	Pine Siskin	Pine Siskin
Red-breasted Nuthatch	Red-breasted Nuthatch	Red-breasted Nuthatch
Red-tailed Hawk	Red-tailed Hawk	Red-tailed Hawk
Ring-billed Gull	Ring-billed Gull	Ring-billed Gull
Ruby-crowned Kinglet	Ruby-crowned Kinglet	Ruby-crowned Kinglet
Ruffled Grouse	Ruffled Grouse	Ruffled Grouse
Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)	Sharp-shinned Hawk (w)
Tree Swallow (sum)	Tree Swallow (sum)	Tree Swallow (sum)
Turkey Vulture	Turkey Vulture	Turkey Vulture
White-throated Sparrow	White-throated Sparrow	White-throated Sparrow
White-winged Crossbill	White-winged Crossbill	White-winged Crossbill
Winter wren	Winter wren	Winter wren
Yellow-rumped Warbler	Yellow-rumped Warbler	Yellow-rumped Warbler
	Baltimore Oriole	Alder Flycatcher
	Brown-headed (Eastern) Cowbird	Baltimore Oriole
	Commom (American) Merganser	Bank Swallow

34 White Rocks	**35A. E. Br. Musq. River**	**35B. W. Br. Musq. River**
	Eastern Kingbird	Barn Swallow (sum)
	Mourning Dove	Black-billed Cuckoo
	Northern Mockingbird	Brown-headed (Eastern) Cowbird
	Domestic Pigeon	Northern Cliff Swallow (sum)
	Ruby-throated Hummingbird	Commom (American) Merganser
		Eastern Kingbird
		Evening (Eastern) Grosbeak
		Gray Catbird
		House (English) Sparrow
		House Finch?
		Indigo Bunting
		Mourning Dove
		Northern Cardinal
		Northern Mockingbird
		Northern Shrike (f,w)
		Oven-bird
		Domestic Pigeon
		Rose-breasted Grosbeak
		Ruby-throated Hummingbird
		Rufous-sided Towhee
		Scarlet Tanager
		Veery
		Yellow Warbler
38	46	64

Table A2.22. Musquash Estuary: List of plankton from the area.
C / I = Confirmed / Inferred, TG = Trophic group.

Species	**TG**	**C/I**
Dinoflagellate		
Alexandrium fundyense	P	C [1]
Ceratium fusus	P	C [1]
Ceratium longipes	P	C [1]
Dinophysis acuminata	P	C [1]
Heterocapsa triquetra	P	C [1]
Prorocentrum micans	P	C [1]
Protoperidinium sp.	P	C [1]
Armoured dinoflagellate	P	C [1]
Unarmoured dinoflagellate	P	C [1]
Diatom		
Achnanthes sp.	P	C [1]
Actinoptychus senarius	P	C [1]
Asterionellopsis glacialis	P	C [1]
Cerataulina pelagica	P	C [1]
Chaetoceros socialis	P	C [1]
Chaetoceros sp.	P	C [1]
Chaetoceros subtilis	P	C [1]
Corethron criophilum	P	C [1]
Coscinodiscus sp.	P	C [1]
Cylindrotheca closterium	P	C [1]
Ditylum brightwellii	P	C [1]
Eucampia zodiacus	P	C [1]
Guinardia delicatula	P	C [1]
Leptocylindrus minimus	P	C [1]
Navicula sp.	P	C [1]
Paralia marina	P	C [1]
Pseudo-nitzschia delicatissima-group	P	C [1]
Rhizosolenia setigera	P	C [1]
Skeletonema costatum	P	C [1]
Thalassiosira oestrupii	P	C [1]
Thalassiosira sp.	P	C [1]
Pennate diatom	P	C [1]
Centric diatom	P	C [1]
Dinobryon sp. (Flagellate)	P	C [1]
Dictyocha speculum (Flagellate)	P	C [1]
Mesodinium rubrum (Cilate)	P	C [1]
Tintinnids (Cilate)	P	C [1]
Flagellate-*Eutreptiella* sp.? (Flagellate)	P	C [1]

APPENDIX 3

Fig. A3.1. Schematic Tree by Ecotype: Rocky Intertidal (numbers refer to number of species identified).

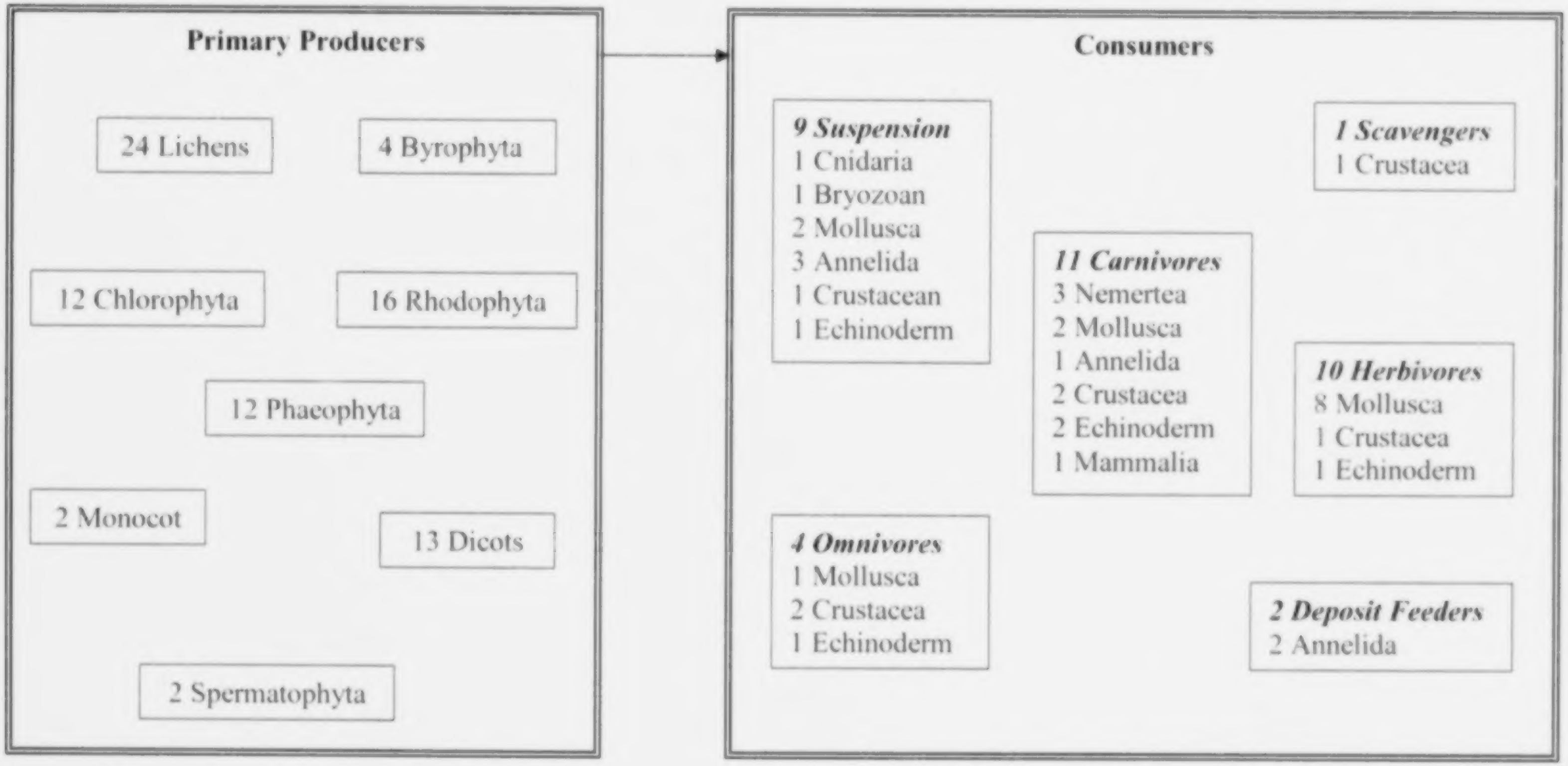
Primary Producers
24 Lichens
4 Byrophyta
12 Chlorophyta
16 Rhodophyta
12 Phaeophyta
2 Monocot
13 Dicots
2 Spermatophyta
Consumers
9 Suspension
1 Cnidaria
1 Bryozoan
2 Mollusca
3 Annelida
1 Crustacean
1 Echinoderm
1 Scavengers
1 Crustacea
11 Carnivores
3 Nemertea
2 Mollusca
1 Annelida
2 Crustacea
2 Echinoderm
1 Mammalia
10 Herbivores
8 Mollusca
1 Crustacea
1 Echinoderm
4 Omnivores
1 Mollusca
2 Crustacea
1 Echinoderm
2 Deposit Feeders
2 Annelida

Fig. A3.2. Schematic Tree by Ecotype: Tidal Pools on Rocky Substratum (numbers refer to number of species identified).

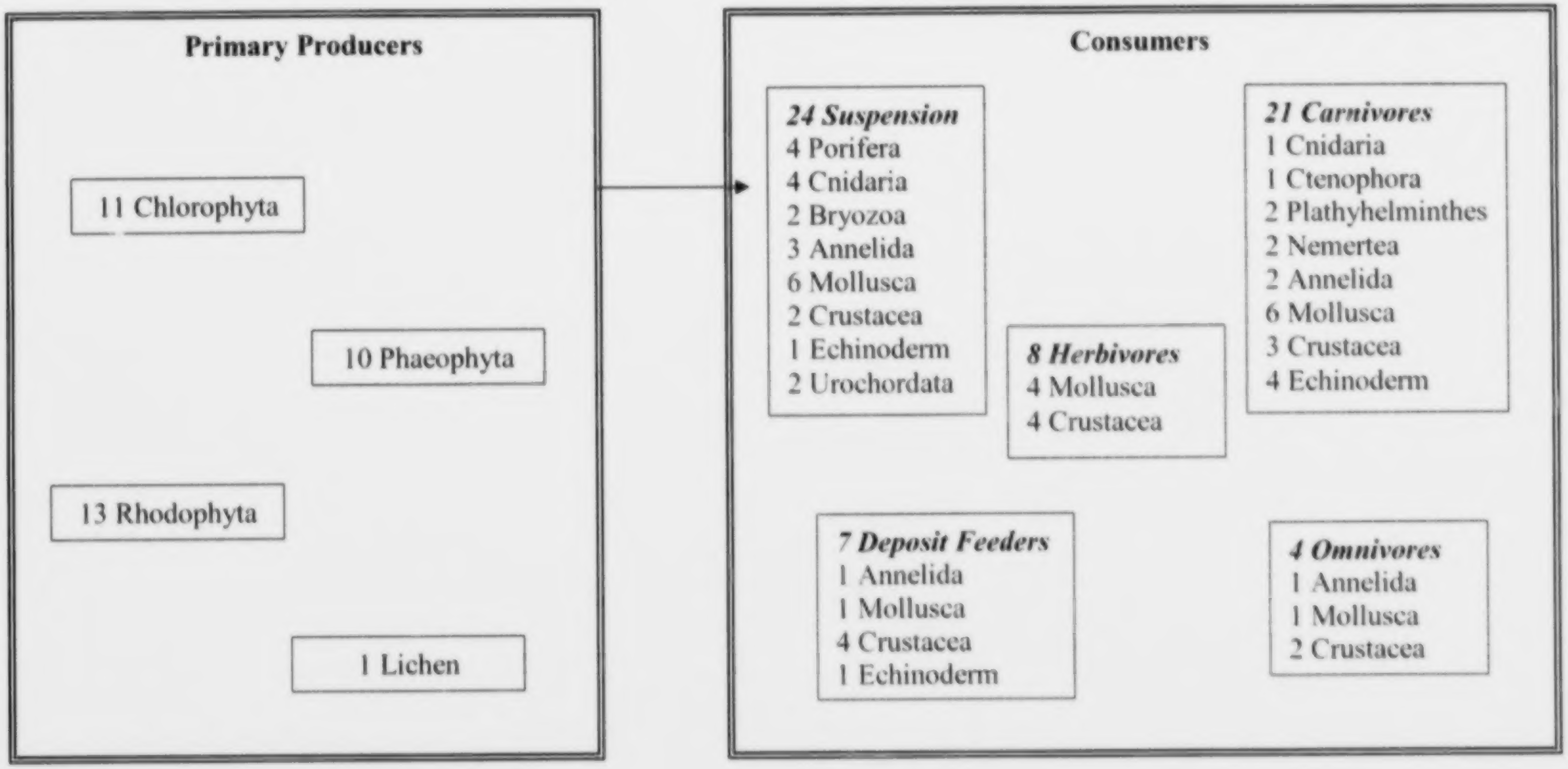
Primary Producers
11 Chlorophyta
10 Phaeophyta
13 Rhodophyta
1 Lichen
Consumers
24 Suspension
4 Porifera
4 Cnidaria
2 Bryozoa
3 Annelida
6 Mollusca
2 Crustacea
1 Echinoderm
2 Urochordata
8 Herbivores
4 Mollusca
4 Crustacea
21 Carnivores
1 Cnidaria
1 Ctenophora
2 Plathyhelminthes
2 Nemertea
2 Annelida
6 Mollusca
3 Crustacea
4 Echinoderm
7 Deposit Feeders
1 Annelida
1 Mollusca
4 Crustacea
1 Echinoderm
4 Omnivores
1 Annelida
1 Mollusca
2 Crustacea

Fig. A3.3. Schematic Tree by Ecotype: Sand & Gravel Intertidal (numbers refer to number of species identified).

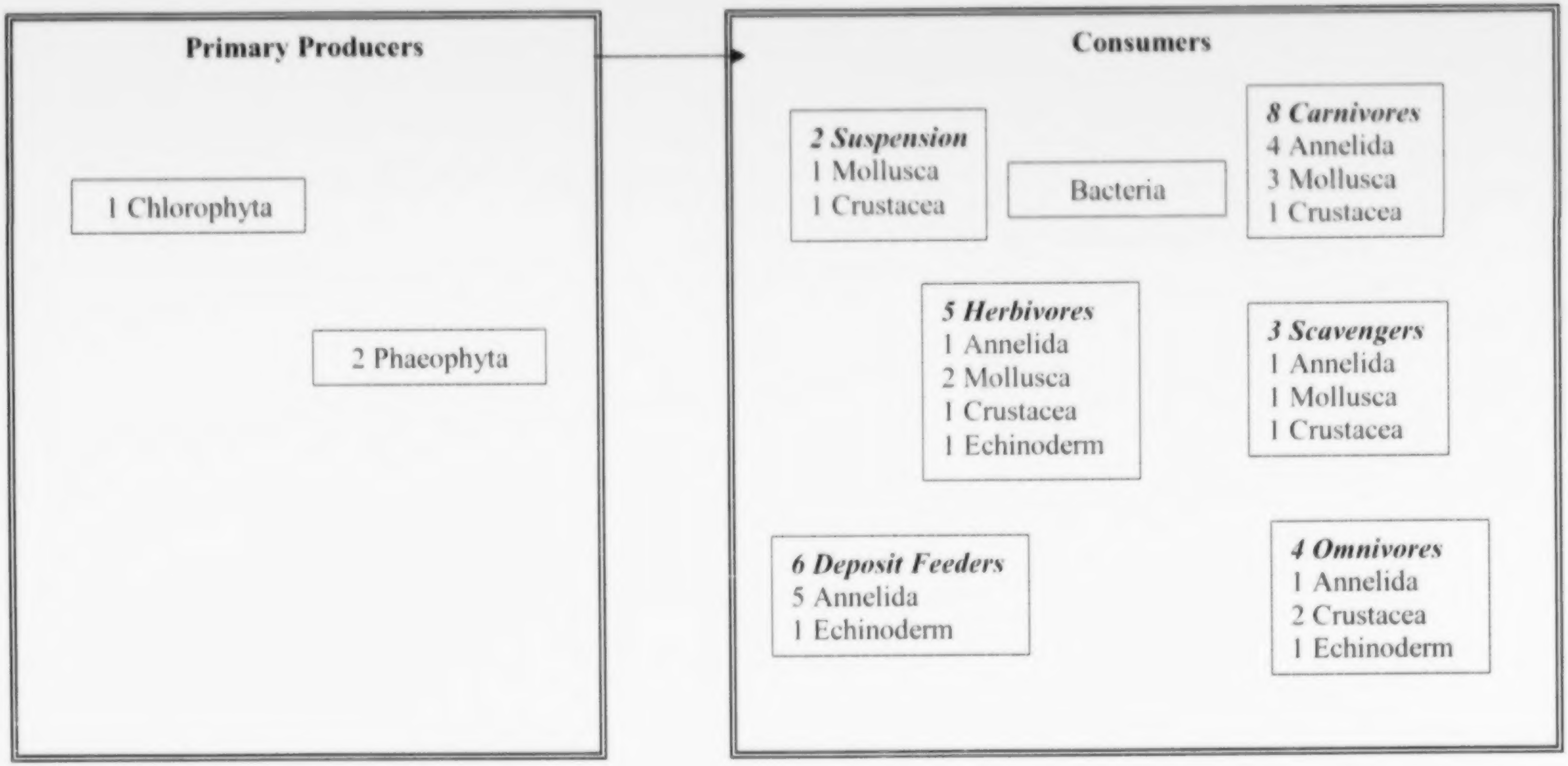
Primary Producers
1 Chlorophyta
2 Phaeophyta
Consumers
2 Suspension
1 Mollusca
1 Crustacea
Bacteria
8 Carnivores
4 Annelida
3 Mollusca
1 Crustacea
5 Herbivores
1 Annelida
2 Mollusca
1 Crustacea
1 Echinoderm
3 Scavengers
1 Annelida
1 Mollusca
1 Crustacea
6 Deposit Feeders
5 Annelida
1 Echinoderm
4 Omnivores
1 Annelida
2 Crustacea
1 Echinoderm

Fig. A3.4. Schematic Tree by Ecotype: Mudflat Intertidal (numbers refer to number of species identified).

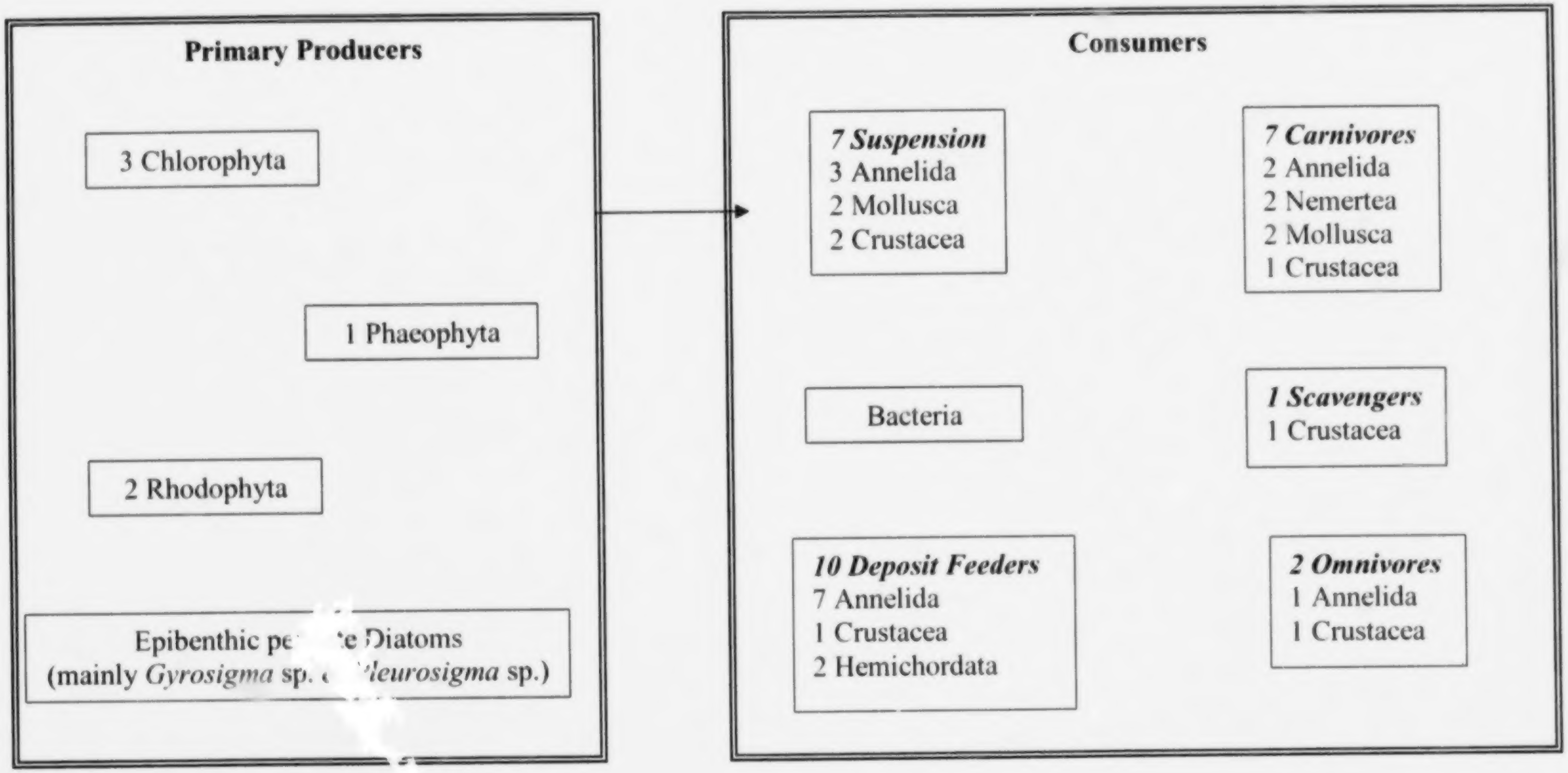
Primary Producers
3 Chlorophyta
1 Phaeophyta
2 Rhodophyta
Epibenthic pe[illegible]te Diatoms
(mainly *Gyrosigma* sp. [illegible] *Pleurosigma* sp.)
Consumers
7 Suspension
3 Annelida
2 Mollusca
2 Crustacea
7 Carnivores
2 Annelida
2 Nemertea
2 Mollusca
1 Crustacea
Bacteria
1 Scavengers
1 Crustacea
10 Deposit Feeders
7 Annelida
1 Crustacea
2 Hemichordata
2 Omnivores
1 Annelida
1 Crustacea

Fig. A3.5. Schematic Tree by Ecotype: Salt Marsh (numbers refer to number of species identified).

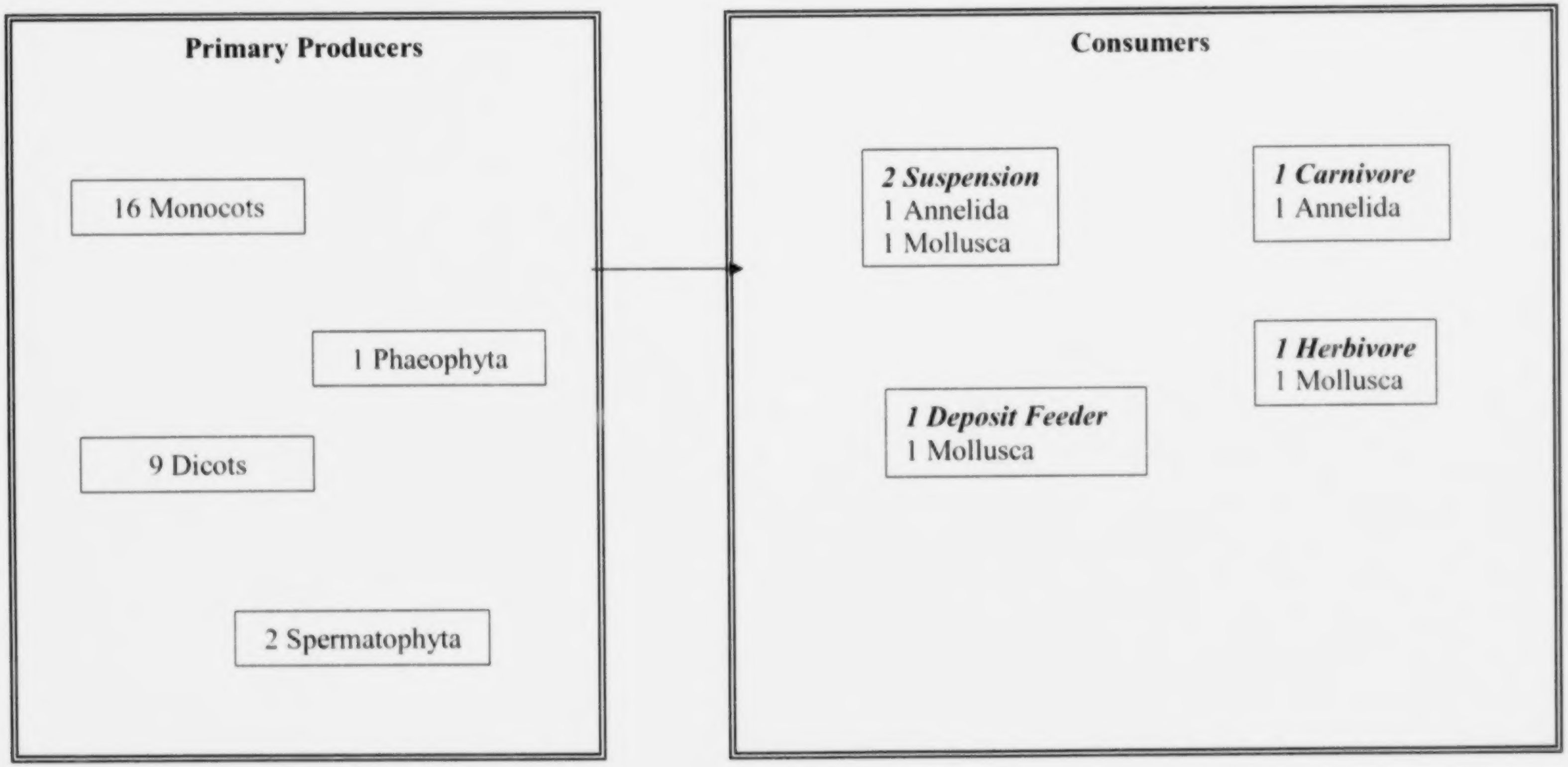
Primary Producers
16 Monocots
1 Phaeophyta
9 Dicots
2 Spermatophyta
Consumers
2 Suspension
1 Annelida
1 Mollusca
1 Carnivore
1 Annelida
1 Herbivore
1 Mollusca
1 Deposit Feeder
1 Mollusca

Fig. A3.6. Schematic Tree by Ecotype: Subtidal Mud & Gravel (numbers refer to number of species identified).

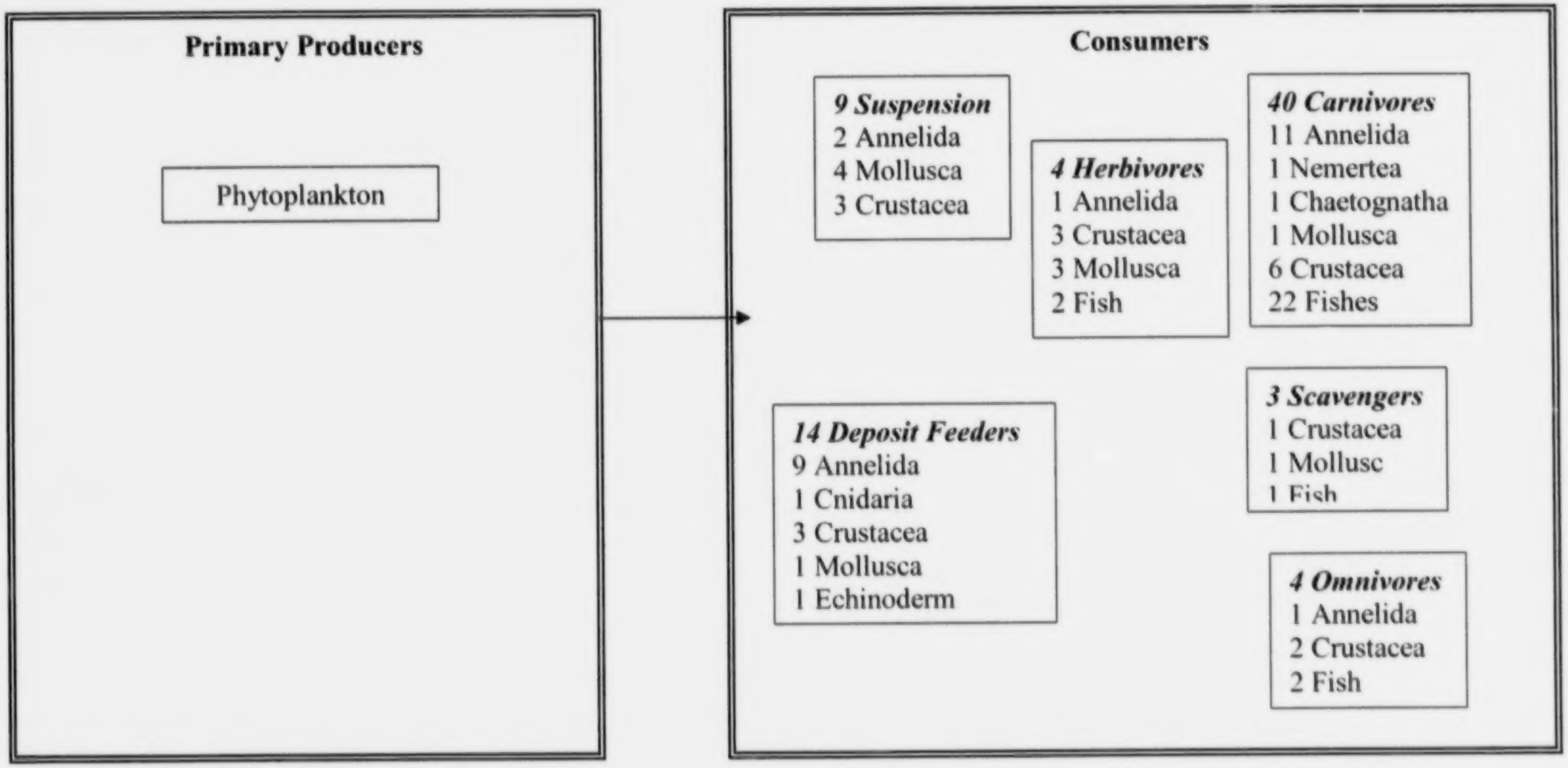
Primary Producers
Phytoplankton
Consumers
9 Suspension
2 Annelida
4 Mollusca
3 Crustacea
4 Herbivores
1 Annelida
3 Crustacea
3 Mollusca
2 Fish
40 Carnivores
11 Annelida
1 Nemertea
1 Chaetognatha
1 Mollusca
6 Crustacea
22 Fishes
14 Deposit Feeders
9 Annelida
1 Cnidaria
3 Crustacea
1 Mollusca
1 Echinoderm
3 Scavengers
1 Crustacea
1 Mollusc
1 Fish
4 Omnivores
1 Annelida
2 Crustacea
2 Fish

Fig. A3.7. Schematic Tree by Ecotype: Subtidal Rocky (numbers refer to number of species identified).

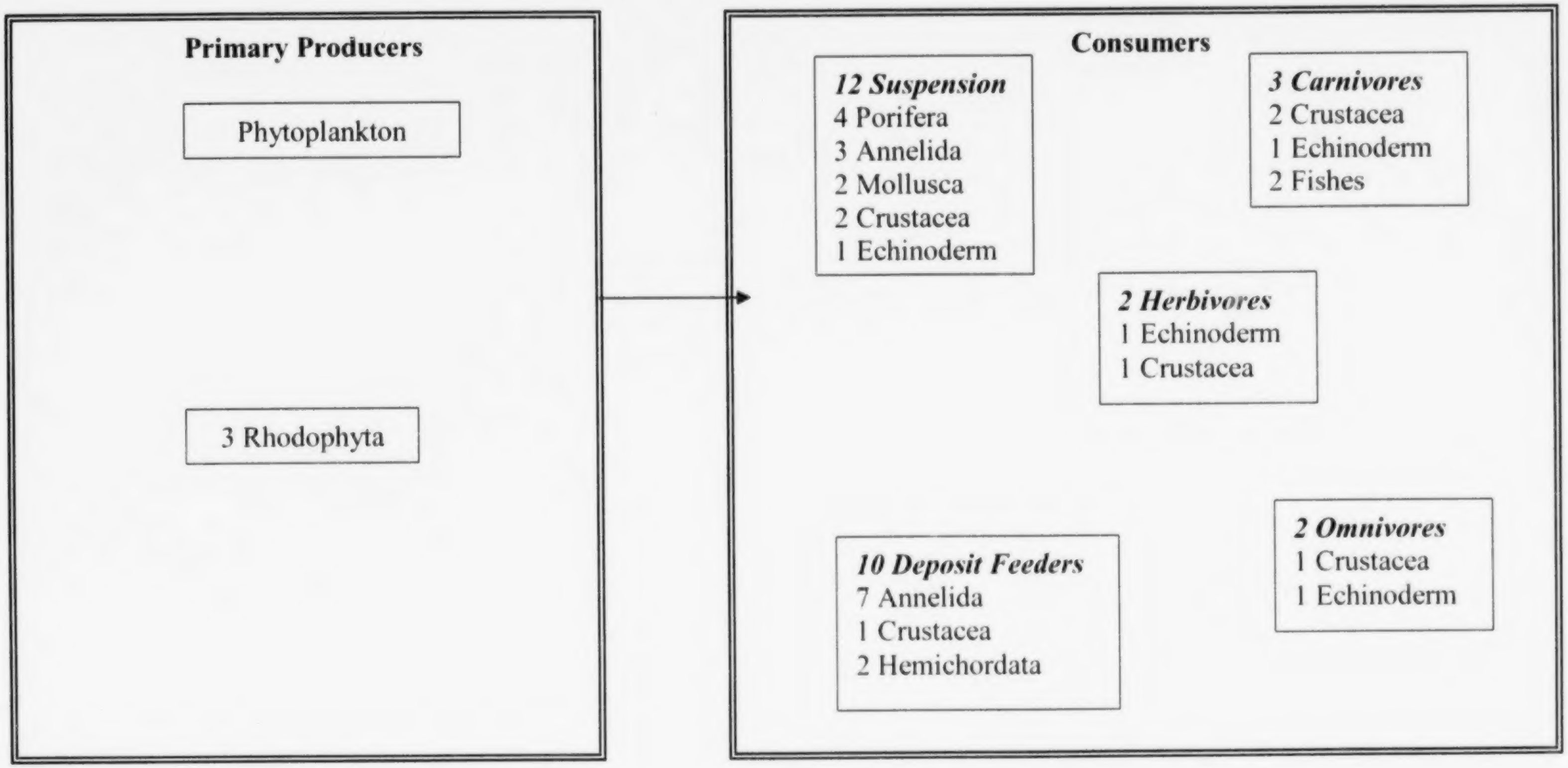
Primary Producers
Phytoplankton
3 Rhodophyta
Consumers
12 Suspension
4 Porifera
3 Annelida
2 Mollusca
2 Crustacea
1 Echinoderm
3 Carnivores
2 Crustacea
1 Echinoderm
2 Fishes
2 Herbivores
1 Echinoderm
1 Crustacea
10 Deposit Feeders
7 Annelida
1 Crustacea
2 Hemichordata
2 Omnivores
1 Crustacea
1 Echinoderm

Table A3.1. Species from each ecotype for which Life History Characteristics have been collated and presented in Table A3.2.

Phylum	Species	Common Name	Trophic Group*	Rocky Intertidal	Tidal Pools	Sand & Gravel Intertidal	Mudflat Intertidal	Salt marsh	Panne	Subtidal mud & sand	Subtidal Rocky
Chlorophyta	*Enterpmorpha intestinalis*	Green alga	P	Y	Y	-	Y	-	-	-	-
	Ulva lactuca	Sea lettuce	P	Y	Y	-	Y	-	-	-	-
	Zostera marina	Eelgrass	P	-	-	Y	Y	-	-	-	-
Phaeophyta	*Ascophyllum nodosum*	Knotted wrack	P	Y	-	Y	-	-	-	-	-
	Fucus spiralis	Rockweed	P	Y	-	-	-	-	-	-	-
	Fucus vesiculosus	Rockweed	P	Y	-	Y	Y	-	-	-	-
Rhodophyta	*Chondrus crispsus*	Irish moss	P	Y	Y	-	Y	-	-	-	-
Mono-cotyledonae	*Hierochloa odorata*	Sweet grass	P	-	-	-	-	Y	-	-	-
	Spartina alterniflora	Cordgrass	P	-	-	-	-	Y	-	-	-
Porifera	*Halichondria panacea*	Breadcrumb Sponge	S	-	Y	-	-	-	-	-	Y
Cnidaria	*Metridium senile*	Plumose anemone	S	-	Y	-	-	-	-	-	-
Annelida	*Capitella capitata*	Threadworm	D	-	-	Y	Y	-	-	-	-
	Hediste (Nereis) diversicolor	Ragworm	S/C	-	-	-	Y	Y	-	Y	-
	Glycera dibranchiata	Two-gilled bloodworm	Sc	-	-	Y	-	-	-	-	-
Mollusca	*Littorina littorea*	Common periwinkle	H	Y	Y	Y	Y	-	-	-	-
	Littorina obtusata	Smooth periwinkle	H	Y	Y	-	-	-	-	-	-
	Littorina saxatilis	Rough periwinkle	H	Y	Y	Y	Y	Y	Y	-	-
	Macoma balthica	Little macoma	D	-	Y	-	Y	Y	-	Y	-
	Mya arenaria	Soft-shelled clam	S	-	-	Y	Y	-	-	Y	-

Phylum	Species	Common Name	Trophic Group*	Rocky Intertidal	Tidal Pools	Sand & Gravel Intertidal	Mudflat Intertidal	Salt marsh	Panne	Subtidal mud & sand	Subtidal Rocky
	Mytilus edulis	Blue mussel	S	Y	Y	-	Y	Y	-	Y	Y
	Placopecten magellanicus	Sea scallop	S	-	-	-	-	-	-	Y	Y?
Crustacea	*Semibalanus balanoides*	Common barnacle	S	Y	Y	Y	Y	-	-	-	Y
	Carcinus maenas	Green crab	C	Y	Y	Y	Y	-	-	Y	Y
	Corophium volutator	Amphipod	D	-	-	-	Y	-	Y	Y	-
	Gammarus oceanicus	Amphipod	H/O	Y	Y	Y	Y	-	-	Y	Y
	Homarus americanus	American lobster	C	-	-	-	-	-	-	-	Y
Urochordata	*Ciona intestinalis*	Sea vase	S	-	-	-	-	-	-	-	Y?
Fish	*Fundulus heteroclitus*	Mummichog	C/O	-	-	-	-	-	Y	Y	Y?
	Gasterosteus aculeatus	Three-spined stickleback	C	-	-	-	-	-	Y	Y	Y?
	Gasterosteus wheatlandi	Blackspotted stickleback	C	-	-	-	-	-	Y?	Y	Y?
	Microgadus tomcod	Atlantic tomcod	C	-	-	-	-	-	-	Y	Y
	Pollachius virens	Pollock	C	-	-	-	-	-	-	Y	Y
	Pseudopleuronectes americanus	Winter flounder	C	-	-	-	-	-	-	Y	Y
	Urophycis tenuis	White hake	C	-	-	-	-	-	-	Y	Y?
	Menidia menidia	Atlantic silverside	C	-	-	-	-	-	-	Y	Y?
	Osmerus mordax mordax	Rainbow smelt	C	-	-	-	-	-	-	Y	-
	Clupea harengus	Atlantic Herring	C	-	-	-	-	-	-	Y	Y?
	Pomolobus (Alosa) pseudoharengus	Alewife	C	-	-	-	-	-	-	Y	-
	Myxocehpalus	Little sculpin	C	-	-	-	-	-	-	Y	Y?

Phylum	Species	Common Name	Trophic Group*	Rocky Intertidal	Tidal Pools	Sand & Gravel Intertidal	Mudflat Intertidal	Salt marsh	Panne	Subtidal mud & sand	Subtidal Rocky
	aenaeus										
	Anguilla rostrata	American eel	Sc	-	-	-	-	-	-	Y	Y?
	Macrozoarces americanus	Ocean pout	C	-	-	-	-	-	-	Y	Y
Mammalia	*Phoca vitulina*	Harbour seal	C	Y	-	-	-	-	-	-	-

* P = primary producer, Sc = scavenger, S = suspension feeder, D = deposit feeder, H = herbivore, C = carnivore, O = omnivore.

Aves (Birds)

Species	Common Name	Trophic Level	Habitat
Somateria mollissima dresseri	Common eider	Carnivore	Outer harbour (subtidal areas)
Calidris pusilla	Semipalmated sandpiper	Carnivore	Mudflat (intertidal areas)
Megaceryle alycon alcyon	Belted kingfisher	Carnivore	All areas
Phalacrocorax auritus	Double-crested Cormorant	Carnivore	Outer harbour (subtidal areas)

Table A3.2. Species life history requirement tables

Species Life Requirements/Habitats: Musquash Estuary		
Species	Green alga *Enteromorpha intestinalis*	Source
Abiotic Factors		
Temperature	- tolerant of high temperatures experienced in rock pools on summer days - reported to be tolerant of temperature as low as -20 °C	[1] [1]
Salinity	- wide range, full salinity to freshwater but cannot survive prolonged exposure at 0 ppt	[2], [3]
Oxygen	- no data found	
Substrate preference	- both sheltered and exposed coasts, on rocks, in pools, on stones, boulders, shells, man-made structures and other algae in upper littoral to sublittoral zones	[2]
Water current and tides	- important in release & distribution of spores & gametes - release in relation to tidal cycles, triggered by the incoming tide as it wets the thallus - have large dispersal shadows, e.g. as far as 35 km	[1] [1] [1]
Cover	- no data found	
Biotic Factors		
Reproduction time	- maximum during summer months	[2]
Reproduction habitat	- needs to be submerged	
Reproduction	- isomorphic alternation between gametophytic and sporophytic generations - can be modified by environmental conditions - vegetative reproduction also possible	[2] [2] [2]
General Traits	- growth rate of 0.15-0.25 cm/day in polluted waters - nitrogen enhances growth making the species a useful indicator of nutrient enrichment, although it also thrives in 'un-enriched' water - may be detached from the substratum and continue growing as a floating mass	[1] [1] [1]
Other	- sensitive to the loss of substrate sediments and substrate disturbance such as dredging - sensitive to smothering - fairly tolerant of desiccation - an important food source for some herbivores such as the *Littorina littorea* - intense and quick response to eutrophication - may provide refuge for supralittoral rock-pool harpacticoid copepods during periods of desiccation	[1] [1] [1] [1] [4] [5]

References

1. Budd, G.C. and P. Pizzola, Ulva intestinalis. *Gut weed. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2004, Marine Biological Association of the United Kingdom. [cited 20/07/2004]: Plymouth.

2. Burrows, E.M., *Chlorophyta*. Seaweeds of the British Isles. Vol. 2. 1991, London: Natural History Museum Publications. 238.
3. Kamer, K. and P. Fong, *Nitrogen enrichment ameliorates the negative effects of reduced salinity on green macroalga* Enteromorpha intestinalis. Mar. Ecol. Prog. Ser., 2001. **218**: 87-93.
4. Perkins, E.J., *The biology of estuaries and coastal waters*. 1974, New York, New York: Academic Press. 678 pp.
5. McAllen, R., Enteromorpha intestinalis *- a refuge for the supralittoral rock-pool harpacticoid copepod Tigriopus brevicornis.* J. Mar. Biol. Assoc. U. K., 1999. **79**: 1125-1126.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Sea lettuce *Ulva lactuca*	Source
Abiotic Factors		
Temperature	- no information found	
Salinity	- tolerates estuarine conditions	[1],[2]
Oxygen	- no information found	
Substrate preference	- on rocks, in pools and other algae in upper littoral to sublittoral, on salt marshes on small stones and shells, loose lying over sand and mud	[1]
Water current and tides	- assumed important in dispersal of gametes & spores	
Cover	- no information found	
Biotic Factors		
Reproduction time	- all times of year, but maximum during summer	[1]
Reproduction habitat	- needs to be submerged	
Reproduction	- alternation of isomorphic gametophyte and sporophyte generations - vegetative reproduction common - depending on season, between 20 & 60% of overall biomass can be allocated monthly to reproduction	[1] [1] [3]
General Traits	- often less than 30 cm long, can be longer on protected shores - perennial holdfast, but blades are annual - an early-successional algae, quickly taking over new substrate on boulders that are cleared by storm disturbance	[1] [4] [3]
Other	- thrives in nutrient rich brackish areas - rich source of iron, eaten in Scotland for many hundreds of years - intense and quick response to eutrophication - relatively tolerant to living in moderate pollution - quite tolerant of stressful conditions and presence often indicates freshwater input or pollution - greatly impaired by extreme desiccation (defined as loss of more than 25% original water content) - consistently outcompeted by *Chondrus crispus* - distribution can be limited by nitrogen concentrations - close correlation between the concentration of seawater inorganic nitrogen and phosphate and tissue nitrogen and phosphorous, respectively - cosmopolitan distribution, simple morphology and ease of growth assessment, along with a graded tolerance and response to stress induced by pollutants all make *Ulva* good bioindicators. - a good indicator of Mn, Fe, Cu, Zn and Pb contaminations; heavy metals inhibit reproduction by interfering with the ability of male and female gametes to find one another via phermones - hydrocarbon pollution inhibits photosynthesis as well as DNA and RNA activities	[2] [5] [5] [4] [3] [3] [3] [3] [3] [3] [3] [3]

References

1. Burrows, E.M., *Chlorophyta*. Seaweeds of the British Isles. Vol. 2. 1991, London: Natural History Museum Publications. 238.
2. Pizzolla, P.F., Ulva lactuca. *Sea lettuce. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2003, Marine Biological Association of the United Kingdom. [cited 20/07/2004]: Plymouth.
3. Kirby, A., Ulva *Ecology [Online] at http://www.mbari.org/staff/conn/botany/greens/anna/frontpages/distrib.htm*. 2001, Monterey Bay Aquarium Research Institute: Moss Landing, CA.
4. Association, N.a.L.C.O.A., Ulva*: Online at http://www.coldoceanaquarium.ca/Exhibits/lettuce.html*. 2004.
5. Perkins, E.J., *The biology of estuaries and coastal waters*. 1974, New York, New York: Academic Press. 678 pp.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Eel grass *Zostera marina*	Source
Abiotic Factors		
Temperature	- growth stops when water gets below 10 °C - vegetative growth occurs in waters of 10 to 15 °C while flowers are produced at > 15 °C - tolerant between about 5 to 30 °C & tolerant of up to 20 °C without stress - tolerance of salinity from 10 - 39 ppt	[1] [1] [2] [3]
Salinity	- tolerates full salinity to brackish waters	[1]
Oxygen	- presence of air spaces (lacunae) suggests a tolerance to low oxygen levels in the short term, but prolonged de-oxygenation, especially if combined with low light penetration may have negative effects	[2]
Substrate preference	- grow well on soft muck as well as on hard sand or gravel in depths of 2 to 10 m - stands greatly accelerate sedimentation in tidal regions but if buried by sand stands degenerate - most beds demonstrate a balance of sediment accretion and erosion	[1] [1] [2]
Water current and tides	- aids in dispersal of fruit-bearing shoots - may carry pieces of rhizomes & seedlings great distances (100 to 1000 m)	[1] [4]
Cover	- no data found	
Biotic Factors		
Reproduction time	- summer (higher temperatures)	[1]
Reproduction habitat	- same as for plant	
Reproduction	- via seeds and rhizome fragmentation - flowers are monosexual, and 500 to 1000 seeds can be produced on a plant - dispersal occurs via fruit-bearing shoots which are susceptible to desiccation - seedling mortality exceedingly high	[1] [1] [1] [4]
General Traits	- fertile shoots are ephemeral and perish at end of season, while vegetative shoots persists - perennial plant, but under stressful conditions may act as annual - life span of 20 to 100 years - age at maturity 1 to 2 year	[1] [4] [2] [2]
Other	- most fruit-bearing shoots eaten by waterfowl & fish - supports a variety of marine animals comprising their winter food - growth rate of 5 m/yr for perennial populations - substratum loss will result in the loss of the shoots, rhizome and probably the seed bank - sediment disturbance, siltation, erosion & turbidity resulting from coastal engineering & dredging activities results in population decline - intolerant of smothering and typically bend over with	[1] [1] [2] [2] [5] [6]

	addition of sediment and are buried in a few centimetres of sediment	
	- increased sediment availability may result in raised beds, resulting in increased likelihood of exposure to low tide, desiccation and high temperatures	[2]
	- should be considered intolerant of any activity that changes the sediment regime where the change is greater than expected due to natural events	[2]
	- mainly subtidal and intolerant of desiccation, intolerant of activities that cause the sediment to drain or dry	[2]
	- increased water flow may increase sediment erosion resulting in loss of population	[2]
	- likely to survive increased turbidity for a month however prolonged increase in light attenuation will probably result in loss or damage of the population	[2]
	- small-scale sediment disturbance may stimulate growth and small patches of sediment allow re-colonization by seedlings	[2]
	- activities such as trampling, anchoring, digging, dredging, power boat and jet-ski wash will likely cause rhizomes to be damaged and seeds to be buried too deep	[6]
	- known to accumulate TBT but no damage was observable in the field	[7]
	- terrestrial herbicides may damage eelgrass beds in the marine environment	[3]
	- leaves and rhizomes accumulate heavy metals, especially in winter	[7]
	- partially protected from oil contamination by subtidal habitat and can occur in the presence of long term, low level, hydrocarbon effluent	[2]
	- nutrient enrichment from high nitrate levels can result in decline of population	[2]
	- eutrophication encourages phytoplankton blooms which increase turbidity and reduce light penetration thereby inhibiting photosynthesis	[2]

References

1. Waisel, Y., *Biology of Halophytes*. 1972, New York: Academic Press.
2. Tyler-Walters, H., Zostera marina. *Common eelgrass. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2004, Marine Biological Association of the United Kingdom. [cited 23/08/2004]: Plymouth.
3. Davison, D.M. and D.J. Hughes, Zostera *biotopes: An overview of dynamics and sensitivity characteristics for conservation management of marine SACs, Vol. 1*, in *UK Marine SACs Project*. 1998, Scottish Association for Marine Science.
4. Phillips, R.C. and E.G. Menez, *Seagrasses*. Smithsonian Contributions to the Marine Sciences, 1988. **34**.
5. Holt, T.J., R.G. Hartnoll, and S.J. Hawkins, *The sensitivity and vulnerability to man-induced change of selected communities: intertidal brown algal shrubs,* Zostera *beds and* Sabellaria spinulosa *reefs*, in *English Nature Research Report No. 234*. 1997, English Nature: Peterborough.
6. Fonseca, M.S., *Restoring seagrass systems in the United States*, in *Restoring the Nation's Marine Environment*, G.W. Thayer, Editor. 1992, Maryland Sea Grant College: Maryland. p. 79 -110.
7. Williams, T.P., J.M. Bubb, and J.N. Lester, *Metal accumulation within salt marsh environments: a review*. Mar. Poll. Bull., 1994. **28**: 277-290.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Rockweed/Knobbed wrack/Knotted wrack *Ascophyllum nodosum*	Source
Abiotic Factors		
Temperature	- eurythermal, can thrive in temperatures -2 to 21 °C - in North America limited to areas with summer temperatures < 22 °C - temperature > 24 °C (from thermal pollution) for several weeks results in damage - can tolerate freezing - between 6 and 15 °C necessary for gamete release	[1] [1] [2] [3] [4]
Salinity	- euyhaline, with a tolerance of about 15 to 37 psu - survive in estuarine waters down to 0 psu, but thrives in normal salinity sea water	[1] [1]
Oxygen	- thrives when exposed to air at low tide - shows seasonal respiration adaptation: respiration ↑ less steeply with ↑ temperature in summer than in winter	[3] [5]
Substrate preference	- requires hard (usually rocky) substrates for holdfast attachment - occupies mid- to low intertidal zone	[1] [1]
Water current and tides	- wave exposure is important in determining distribution - increased wave exposure results in plant breakage & may prevent settlement of zygote	[1] [1]
Cover	- strives in areas where it is exposed at low tide	[1]
Biotic Factors		
Reproduction time	- April to June, gametes are released after ripe receptacles are exposed to air overnight	[1]
Reproduction habitat	- fertilization occurs in the water	[1]
Reproduction	- reproduce vegetatively by basal and lateral shoots - sexual reproduction is oogamous, receptacles produced the previous April to June ripen and release gametes during April to June the following year - perennial with separate male and female plants - germlings take 5 yrs to mature	[1] [1] [1] [6]
General Traits	- vesicles large in areas exposed to wide variations in salinity - held to substratum by discoid holdfasts - slow growth (especially in germlings) but long lived, up to several decades - growth is apical, 90% of apical elongation takes place in the 0 to 5 mm zone behind apex - repeatedly sloughs entire epidermis which contributes to shedding of epiphytes - obligate epiphyte *Polysiphonia lanosa* found primarily on this host and has deep penetrating rhizoids - can grow up to 15 yrs old before breakage of fronds - may attain age of 30 yrs in the Bay of Fundy	[7] [7] [3] [3] [8] [9] [3] [5]
Other	- shoot age can be determined based on shoot structure - light, inclination, competition, epi-endophytes, and human influence can affect distribution	[1] [1]

	- somewhat sensitive to pollution	[1]
	- settlement of zygotes and rhizoid production occurs in about 10 days after fertilization	[1]
	- growth of germlings is very slow making them targets of *Littorina*	[1]
	- poor recruitment of germlings to shore, reason unclear	[10]
	- fresh weight varies throughout year	[1]
	- substratum loss will result in loss of population	[3]
	- poor recruitment rates to cleared areas	[1]
	- can withstand some smothering by sediment at high tide, but low tide smothering will inhibit photosynthesis	[1]
	- can withstand some amount of siltation	[1]
	- tolerant of desiccation, but productivity is inhibited when water loss exceeds 50%	[1]
	- increase in flow rate can result in plants being torn off	[1]
	- increased turbidity will reduce production by reducing photosynthesis during immersion	[1]
	- intolerant of physical abrasion from trampling	[1]
	- disappearance of plant from highly polluted sites likely due to reduced success of germlings	[11]
	- adult plants are fairly resistant to heavy metal pollution	[1]
	- hydrocarbon contamination reduces photosynthesis and inhibits the release of gametes	[1]
	- eutrophication results in increased growth of epiphytic green algae (e.g. *Enteromorpha*) causing decreased growth in the plant	[1]

References

1. Baardseth, E., *Synopsis of biological data on knobbed wrack* Ascophyllum nodosum *(Linnaeus) Le Jolis*, in *FAO Fish. Synposis*. 1970, FAO: Rome. 41 pp.
2. Lobban, C.S. and P.J. Harrison, *Seaweed ecology and physiology*. 1997, Cambridge: Cambridge University Press.
3. Hill, J.M. and N. White, Ascophyllum nodosum. *Knotted wrack. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2003, Marine Biological Association of the United Kingdom. [cited 8/11/2004]: Plymouth.
4. Bacon, L.M. and R.L. Vadas, *A model for gamete release in* Ascophyllum nodosum *(Phaeophyta)*. J. Phycol., 1991. **27**: 166-173.
5. Luning, K., *Seaweeds: Their Environment, Biogeography and Ecophysiology*. 1990, New York: John Wiley & Sons.
6. Sundene, O., *Growth and reproduction in* Ascophyllum nodosum *(Phaeophyceae)*. Nor. J. Bot., 1973. **20**: 249-255.
7. Sharp, G., Ascophyllum nodosum *and its harvesting in Eastern Canada*, in *Case studies of seven commercial seaweed resources*, M.S. Doty, J.F. Caddy, and B. Santelices, Editors. 1986, FAO: Rome. p. 3-48.
8. Filion-Myclebust, C. and T.A. Norton, *Epidermis shedding in the brown seaweed* Ascophyllum nodosum *(L.) Le Jolis, and its ecological significance*. Mar. Biol. Letters, 1981. **2**: 45-51.

9. Levin, P.S. and A.C. Mathieson, *Variation in host-epiphyte relationship along a wave exposure gradient.* Mar. Ecol. Prog. Ser., 1991. **77**: 271-278.

10. Printz, H.S., *Investigations of the failure of recuperation and re-populating in cropped* Ascophyllum *areas.* Avhandlinger utgitt av Det Norske Videnskap-Akademi i Oslo, 1959. **3**.

11. Sjoetun, K. and T.E. Lein., *Experimental oil exposure of* Ascophyllum nodosum. J. Exp. Mar. Biol. Ecol., 1993. **170**: 197-212.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Bladder wrack *Fucus spiralis*	Source
Abiotic Factors		
Temperature	- eurythermal, in New Hampshire, USA, -0.5 to 23.1 °C - maximal growth occurs at 18 to 19 °C during summer - optimum temperature for growth is 15 °C	[1] [1] [2]
Salinity	- euryhaline, in New Hampshire, USA, 3 to 32 ‰ - can extend into estuaries up to the 10 psu isohaline	[1] [3]
Oxygen	- reduced oxygen unlikely to have effect as algae produces oxygen by photosynthesis	[3]
Substrate preference	- in New Hampshire found on coarse metasedimentary and metavolcanic rocks that have cracks & fissures	[1]
Water current and tides	- important in the distribution of gametes & zygotes	[1]
Cover	- provides shelter for other intertidal organisms	[1]
Biotic Factors		
Reproduction time	- July to September maximum reproduction time in New Hampshire, USA	[1]
Reproduction habitat	- gametes shed into water - plants at bottom of distribution belt larger and more reproductive	[1] [1]
Reproduction	- usually by plants ≥ 9 cm long (> 2 yrs old), larger plants produce more receptacles - receptacle initiation occur during winter	[1] [1]
General Traits	- perennial plant - silt impacts negatively on distribution - capable of extracting & concentrating trace elements from water	[1] [4] [5]
Other	- occupies high intertidal, exposed to extreme variations of atmospheric conditions - spends 90% of time out of water & able to survive 70 to 80% water loss, beyond this irreversible damage occurs - abundant in semi-exposed and sheltered open coast - in New Hampshire very few plant were > 35 cm - average life span of 2 to 2.5 yrs, some to 4 yrs - growth rate of 1.1 cm/month - will tolerate moderate eutrophication from sewage - loss of substratum will result in loss of population - smothering by sediment on immersed plants will cause reduction in photosynthesis - increased flow rate will cause some plants to torn off the substratum - abrasion from human trampling kills germlings & causes damage to fronds of established plants - germlings intolerant of heavy metal pollution while adults accumulate them - show limited intolerance to hydrocarbon oils	[1] [3] [1] [1] [1] [3] [5] [3] [3] [3] [3] [6] [6]

References

1. Niemeck, R.A. and A.C. Mathieson, *An ecological study of* Fucus spiralis *L.* J. Exp. Mar. Biol. Ecol., 1976. **24**: 33-48.
2. Luning, K., *Seaweeds: Their Environment, Biogeography and Ecophysiology*. 1990, New York: John Wiley & Sons.
3. White, N., Fucus spiralis. *Spiral wrack. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2003, Marine Biological Association of the United Kingdom. [cited 8/11/2004]: Plymouth.
4. Hazlett, A. and R. Seed, *A study of* Fucus spiralis *and its associated fauna in Strangford Lough, Co. Down.* Proc. Royal Irish Acad., 1976. **76B**: 607-618.
5. Perkins, E.J., *The biology of estuaries and coastal waters*. 1974, New York, New York: Academic Press. 678 pp.
6. Holt, T.J., R.G. Hartnoll, and S.J. Hawkins, *The sensitivity and vulnerability to man-induced change of selected communities: intertidal brown algal shrubs,* Zostera *beds and* Sabellaria spinulosa *reefs*, in *English Nature Research Report No. 234.* 1997, English Nature: Peterborough.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Bladder wrack *Fucus vesiculosus*	Source
Abiotic Factors		
Temperature	- can tolerate -30 °C (for several weeks) up to as high as 30 °C	[1]
	- freeze tolerance may vary seasonally: -30 °C in summer to –60 °C in winter	[2]
	- heat tolerance ↑ by 5 °C if 30% water loss occur	[1]
Salinity	- prefers 18 to 40 psu (estuarine to marine)	[3]
	- grows well in 8 to 34‰	[1]
	- can tolerate salinity down to 11 psu	[3]
Oxygen	- respiration declines at 25 °C in winter and 30 °C in summer	[4]
Substrate preference	- common in midlittoral on, moderately exposed to very sheltered hard rocky shores	[3]
	- may be attached to boulders, cobble, sometimes gravel	[3]
Water current and tides	- help in dispersal of gametes and zygotes	[3]
Cover	- may provide cover for intertidal species	[3]
Biotic Factors		
Reproduction time	- in UK up to 6 months (mid-winter to late summer) peaking in May and June	[3]
Reproduction habitat	- eggs and sperms are produced in receptacles	[3]
	- gametes released into water & external fertilization occurs	[3]
	- zygotes begin development wherever they settle	[3]
Reproduction	- annual episodic	[3]
	- plants are dioecious and can be highly fecund producing more than 1000 receptacles on each plant	[3]
	- receptacles takes about 3 months to develop	[3]
General Traits	- can grow up to 2 metres long and live for about 3 years	[3]
	- air bladders produced annually	[3]
	- growth rate of 0.48 cm/week	[3]
Other	- will tolerate moderate eutrophication from sewage	[5]
	- morphology varies with environmental conditions	[3]
	- plant in exposed location may lose air bladders	[3]
	- loss of substratum results in loss of population	[3]
	- cleared areas take about 1 to 3 years for full recovery	[3]
	- can withstand moderate amount of smothering	[3]
	- can withstand desiccation down to 30% water content	[3]
	- increases in water flow rate may cause plants to be torn off the substratum	[3]
	- increased turbidity results in reduced photosynthesis	[3]
	- abrasions from trampling damages fronds & germlings	[3]
	- highly intolerant of chlorate from pulp mill effluents	[3]
	- accumulates heavy metals and can be used as indicator of these	[3]
	- limited tolerance to oil pollution	[3]
	- increased nutrients may lead to eutrophication, overgrowth by green algae and reduced oxygen levels	[3]

References

1. Luning, K., *Seaweeds: Their Environment, Biogeography and Ecophysiology*. 1990, New York: John Wiley & Sons.
2. Parker, J., *Seasonal changes in cold-hardiness of* Fucus vesiculosus. Biol. Bull. Woods Hole, 1960. **119**: 474-478.
3. White, N., Fucus vesiculosus. *Bladder wrack. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2003, Marine Biological Association of the United Kingdom. [cited 20/07/2004]: Plymouth.
4. Kanwisher, J.W., *Photosynthesis and respiration in some seaweeds*, in *Some contemporary studies in marine science*, H. Barnes, Editor. 1966, George Allen & Unwin: London. p. 407-420.
5. Perkins, E.J., *The biology of estuaries and coastal waters*. 1974, New York, New York: Academic Press. 678 pp.

Species Life Requirements/Habitats: Musquash Estuary (after [1])		
Species	Irish moss *Chondrus crispus*	Source
Abiotic Factors		
Temperature	- broad tolerance - in New Hampshire in -1 to 19 °C - spores in culture: no growth at 26 °C, total mortality at 35 to 40 °C - photosynthesis recovered after 3 hr at -20 °C but not after 6 hr	[2] [3] [4] [5]
Salinity	- broad tolerance, common in estuarine conditions - in New Hampshire in 16 to 32 ‰ - photosynthesis occurs between 10 to 50 psu, max at 30 - tolerant of hypersaline conditions - low salinity may suppress growth	[2] [3] [6] [7] [7]
Oxygen	- low O_2 may impair both respiration and photosynthesis	[7]
Substrate preference	- basement rocks and boulder in littoral fringe down to 20 m below mean low water depending on wave action, transparency and local topographic conditions	[2]
Water current and tides	- can thrive in tidal rapids with currents up to 5.5 knots	[3]
Cover	- no data found	
Biotic Factors		
Reproduction time	- maximal spore release occurs May to June	[2]
Reproduction habitat	- requires water for release of spores	[2]
Reproduction	- dioecious, triphasic reproduction - colourless spermantangia produced in sori on terminal portions of young branches - carpospores (cells with eggs) and tetraspores produced - vegetative reproduction via holdfast regeneration - reproductive maturity 20 months to 5 yrs - number of spores released 8 x 10^{10}/m^2/year - viability of spores was low (<30%) in Nova Scotia	[2] [2] [2] [2] [2] [8] [9]
General Traits	- perennial, discoid holdfast with erect fronds in tufts - holdfast grows very slowly 2 yrs to get to 4 mm^2	[2] [2]
Other	- basis of multimillion dollar phycocolloid industry - maximal growth during late spring or summer - growth rate of 0.37 mm/day in Maine - peak growth occurs May to November - major herbivore is green sea urchin - appearance highly variable depending on shore exposure level - tendency to turn green in strong sunlight - fronds have life span of 2 to 3 yrs - holdfast longer lived, regeneration capable after disturbance - have low tolerance to sewage pollution - loss of substratum will result in loss of population - recovery of totally denuded areas takes about 5 years - spores and propagules adversely affected by layer of sediment reducing light levels by 98%	[2] [2] [4] [10] [2] [7] [7] [7] [3] [11] [7] [12] [13]

References

1. Parker, M.A. and R.J. Rutherford, *Musquash Ecosystem Framework Development*. 2003, East Coast Aquatics & Thaumas Environmental: Dartmouth, Nova Scotia. 39 pp.
2. Pringle, J.D. and A.C. Mathieson, Chondrus crispus. Pages 49-122. In *Case studies of seven commercial seaweed resources*, M.S. Doty, J.F. Caddy, and B. Santelices, Editors. 1986, FAO Fish. Tech. Pap. 281. FAO, Rome.
3. Mathieson, A.C. and R.L. Burns, *Ecological Studies of Economic Red Algae. 5. Growth and reproduction of natural and harvested populations of* Chondrus crispus *in New Hampshire*. J. Exp. Mar. Biol. Ecol., 1975. **17**:137-156.
4. Prince, J.S. and J.M. Kingsbury, *The ecology of* Chondrus crispus *at Plymouth, Massachusetts. 3. Effect of elevated temperature on growth and survival.* Biol. Bull. Woods Hole, 1973. **145**: 580-588.
5. Dudgeon, S.R., I.R. Davidson, and R.L. Vadas, *Effect of freezing on photosynthesis of intertidal macroalgae: tolerance of* Chondrus crispus *and* Mastocarpus stellatus *(Rhodophyta).* Mar. Biol., 1989. **101**: 107-114.
6. Bird, N.L., L.C.-M. Chen, and J. McLachlan, *Effects of temperature, light and salinity of growth in culture of Chondrus crispus, Furcellaria lumbricalis, Gracilaria tikvahiae (Gigartinales, Rhodophyta), and* Fucus serratus *(Fucales, Phaeophyta).* Bot. Marina, 1979. **22**: 521-527.
7. Rayment, W.J. and P.F. Pizzolla, Chondrus crispus. *Carrageen. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2003, Marine Biological Association of the United Kingdom. [cited 15/03/2004]. Plymouth.
8. Fernandez, C. and M.P. Menendez, *Ecology of* Chondrus crispus *on the northern coast of Spain. 2. Reproduction.* Bot. Marina, 1991. **34**: 303-310.
9. Scrosati, R., et al., *Reproductive ecology of* Chondrus crispus *(Rhodophyta, Gigartinales) from Nova Scotia, Canada.* Bot. Marina, 1994. **37**: 293-300.
10. Chopin, T., et al., *Open water aquaculture of the red alga Chondrus crispus in Prince Edward Island, Canada.* Hydrobiologia, 1999. **398/399**: 417-425.
11. Perkins, E.J., *The biology of estuaries and coastal waters*. 1974, New York, New York: Academic Press. 678 pp.
12. Minchinton, T.E., R.E. Schiebling, and H.L. Hunt, *Recovery of an intertidal assemblage following a rare occurrence of scouring by sea ice in Nova Scotia, Canada.* Bot. Marina, 1997. **40**: 139-148.
13. Vadas, R.L., S. Johnson, and T.A. Norton, *Recruitment and mortality of early post-settlement stages of benthic algae.* Birtish Phycol. J., 1992. **27**: 331-351.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Indian/Vanilla/Sweet grass *Hierochloe odorata*	Source
Abiotic Factors		
Temperature	- extremely cold hardy, cold weather induces dormancy once ground reaches 40 °F (4.4 °C) - minimum survival temperature -38 °F	[1] [1]
Salinity	- medium soil salinity tolerance	[1]
Oxygen	- medium soil anaerobic tolerance	[1]
Substrate preference	- prefers light (sandy), medium (loamy) and heavy (clay) soils - prefers acid, neutral and basic (alkaline) soils - requires dry moist or wet soil in fresh or brackish areas: meadows, at edges of woods, bogs & marshes - normally not found in pure stands but among other grasses & shrubs in mid-successional communities	[1] [1] [1] [1]
Water current and tides	- no information available	
Cover	- no information available	
Biotic Factors		
Reproduction time	- flowering from April to May (spring)	[1]
Reproduction habitat	- native perennial	[1]
Reproduction	- flowers are hermaphrodite (have both male & female organs) & pollinated by wind - inflorescence: open, pyramid-shaped, golden-brown panicle with slender branches - spikelets have 3 florets with awnless lemmas; glumes are thin, translucent & nearly equal in length - fruit is caryopsis - seed germination usually takes about 2 weeks	[1] [1] [1] [1] [1]
General Traits	- has a very aggressive root system and has been planted to stabilize banks - growing to 0.6 m by 0.6 m and rising from slender deep creeping rhizomes - in spring rhizomes produce inconspicuous fruiting stems with sparse, short leaves - longer leaves appear on separate sterile shoots and can reach 18+ inches - leaves are few, rough-edged & have shiny hairless undersides - low drought tolerance - intermediate shade tolerance	 [1] [1] [1] [1] [1] [1]
Other	- essential oil from the leaves is used as a food flavouring in sweets and soft drinks - has a strong vanilla-like flavour - leaves are added to vodka as a flavouring - used as a colouring agent, perfume, hair wash - dried leaves are used as a ceremonial incense or smudge among Aboriginal Indians - sweet smell is from coumarin, a natural anticoagulant & has potential to cause liver damage & haemorrhages	[1] [1] [1] [1] [1] [1]

	- browsed on by rodents and small mammals - population on decline due to harvesting both for commercial and personal use - low germination from seeds (25-30%)	[1] [1] [1]

References

1. USDA-NRCS, *The PLANTS Database (http://plants.usda.gov)*. 2004, National Plant Data Center: Baton Rouge, LA 70874-4490 USA.

Species Life Requirements/Habitats: Musquash Estuary (after [1])		
Species	Cord grass *Spartina alterniflora*	Source
Abiotic Factors		
Temperature	- survives 4 months below freezing each year - seed germination temperature-sensitive, poor < 4 °C - cold winter temperatures are required for successful growth	[2] [3] [3]
Salinity	- prefers moderate salinity concentrations and places high demands on iron supplies - ideal salinity range of 8 to 33 ppt (brackish to saline) - will tolerate regular inundations with 0 to 35 ppt - dieback occurs at >45 ppt - high salinity inhibits seed germination and growth	[4] [5] [5] [6] [3]
Oxygen	- of concern in the anoxic substrate - can be found on sandy aerobic and anaerobic soils - have extensive, deep, and well aerated anchoring root system as well as superficial fine absorbing roots	[4] [5] [3]
Substrate preference	- colonizes clayey to sandy substrates with variably thick silt cover - does not grow on sandy substrate - critically sensitive to reduced soil sulphides, a condition common in anaerobic & brackish marsh soils - requires tidal inundation with water depths of 1" to 18" - will not survive in soils with extremely high level of organic matter	[4] [4] [5] [5] [5]
Water current and tides	- on low sites covered by water 10-17 hours per day - avoids areas of turbulent water	[4] [5]
Cover	- in dense stands so thick that sediment surface receive little sunlight	[4]
Biotic Factors		
Reproduction time	- perennial plant, in September & October seedheads emerge	[4],[5]
Reproduction habitat	- non-sandy, quiet waters of moderate salinity	[4]
Reproduction	- by seeds and vegetatively by long hollow rhizomes - each spike holds 12 to 15 two or three inch long spikelets, flowers are wind pollinated - long submersion of seeds may stimulate germination - vitality of seeds retained up to 14 weeks but cannot withstand desiccation and temperatures of 25 °C	[4] [5] [3] [3]

	- a poor seed producer: most seeds are empty, damaged, or sterile, seed fertility is low	[5]
General Traits	- attains height of 50 – 100 cm	[4]
	- seedlings may reach 20 cm after one growth season	[3]
	- may take as long as 20 yrs to change from a few scattered clumps to a continuous meadow	[3]
	- high capacity to withstand immersion	[3]
	- facultative halophyte: will tolerate salt but salt is not required for growth	[5]
Other	- stands may produce marine peat	[4]
	- as a salt-secreting halophyte, have capacity to remove salt via salt glands	[3]
	- stands absorb waver energy and screen suspended solids from intertidal waters	[5]
	- will tolerate petroleum contaminated soils	[5]
	- provides food & cover for a number of marsh birds & mammals	[5]
	- flower beetles may limit seed production	[5]
	- heavy floating debris can cause mechanical damage	[5]

References

1. Parker, M.A. and R.J. Rutherford, *Musquash Ecosystem Framework Development*. 2003, East Coast Aquatics & Thaumas Environmental: Dartmouth, Nova Scotia. 39 pp.
2. Long, S.P. and C.F. Mason, *Saltmarsh ecology*. 1983, New York: Blackie, Distributed in the USA by Chapman and Hall. viii +160 pp.
3. Waisel, Y., *Biology of Halophytes*. 1972, New York: Academic Press.
4. Thannheiser, D. and G.F. Bennett, *The coastal vegetation of Eastern Canada*. Occasional Papers in Biology No. 8. 1984, St. John's: Memorial University of Newfoundland. 212 pp.
5. USDA-NRCS, *The PLANTS Database (http://plants.usda.gov)*. 2004, National Plant Data Center: Baton Rouge, LA 70874-4490 USA.
6. Woodhouse Jr., W.W., E.D. Seneca, and S.W. Broome, *Marsh building with dredge spoil in North Carolina*. Bull. North Carolina Argi. Exp. Stat., 1972. 445.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Breadcrumb sponge *Halichondria panicea*	Source
Abiotic Factors		
Temperature	- wide distribution in the North Atlantic means a wide temperature tolerance - tissues can be damaged if exposed to frost	[1] [2]
Salinity	- occurs from full to low salinity - prolonged exposure to fresh or almost fresh water is likely to result in mortality	[1] [1]
Oxygen	- likely needs a good supply of oxygen due to the need for flowing water, but no other information found	[1]
Substrate preference	- found in damp habitats on the shore including rock pools, under boulders and overhangs - in deeper water: abundant in wave exposed or tideswept situations often dominating kelp stipes	[1] [1]
Water current and tides	- important in transport of food to sponge - important in larval distribution	[1] [1]
Cover	- no information found	
Biotic Factors		
Spawning time	- separate sexes; seasonally distinct, very short reproductive period in the Baltic Sea - oviparous; lecithotrophic larvae released in spring through to June	[3] [3]
Spawning habitat	- same as living habitat	[1]
Eggs	- no information found	
Foods	- active suspension feeder on phytoplankton	[1]
Other	- on the shore and in shallow depths, may be green due to the presence of algal symbionts in tissue, in the shade and deeper water: cream-yellow in colour - smell strongly of seaweed - growth rate of 1.6% increase in percentage area/day between March & August in Baltic Sea - in the Gulf of Maine: growth rate of 5% per week with highest growth rates in lower currents - life span of 3 yrs - unlikely to survive substratum loss but settlement of new colony likely within one yr & growth is rapid - highly intolerant of smothering by sediment - able to survive in areas with suspended sediment; has a mechanism for sloughing off complete outer tissue layer together with any debris - able to withstand some desiccation but bleaching and tissue death is likely at the edges of the colony, re-growth will most likely occur - increased water flow will result in larger colonies being torn-off or swept away - decreased water flow can result in de-oxygenation and poor food supply - increased turbidity will result in decease survival of the	[1] [1] [4] [5] [6] [1] [1] [7] [1] [1] [1] [1]

	symbiotic algae living in the sponge, but sponge will survive	
	- unlikely to survive abrasion and physical disturbance, but slight damages can be repaired quickly	[1]
	- very little information has been found, appears to survive oil spill	[1]

References

1. Hiscock, K., Halichondria panicea. *Breadcrumb sponge. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2002, Marine Biological Association of the United Kingdom. [cited 8/11/2004]: Plymouth.
2. Crisp, D.J., *The effects of the severe winter of 1962-63 on marine life in Britain*. J. Anim. Ecol., 1964. **33**: 165-210.
3. Witte, U., D. Bartel, and O. Tendal, *The reproductive cycle of the sponge* Halichondria panicea *Pallas (1766) and its relationship to temperature and salinity*. J. Exp. Mar. Biol. Ecol., 1994. **183**: 42-52.
4. Barthel, D., *On the ecophysiology of the sponge* Halichondria panicea *in Kiel Bight. II. Biomass, production, energy budget and integration in environmental processes*. Mar. Ecol. Prog. Ser., 1988. **43**: 87-93.
5. Leichter, J.J., and J.D. Witman, *Water flow rates over subtidal rock walls: relation to distributions and growth rates of sessile suspension feeders in the Gulf of Maine. Water flow and growth rates*. J. Exp. Mar. Biol. Ecol., 1997. **209**: 293-307.
6. Fish J.D. and S. Fish, *A Student's Guide to the Seashore*. 1996, Cambridge: Cambridge University Press.
7. Barthel, D. and B. Wolfrath, *Tissue sloughing in the sponge* Halichondria panicea: *a fouling organism prevents being fouled*. Oecologia, 1989. **78**: 357-360.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Plumose anemone *Metridium senile*	Source
Abiotic Factors		
Temperature	- no evidence of adverse effects of short-term temperature increase on anemones occurring, for instance, adjacent to thermal effluents	[1]
Salinity	- can be found in waters down to 10 ‰ but prefers full salinity	[2]
	- on exposure to 50% seawater, animals retracted their tentacles whilst those exposed to fluctuating salinity, contracted their body wall & produced copious mucus	[3]
Oxygen	- LC_{50} under anoxic conditions of 3 weeks, no survival beyond 6 weeks, animals may drift away from anoxic conditions during first week	[4],[5]
	- diminishes body surface area under low O_2	[4],[5]
Substrate preference	- hard substratum in overhangs, caves & beneath boulders on the lower shore, and on pier piles & rock	[1]

	faces to at least 100 m	
Water current and tides	- thrives in moderate to high flow regimes - higher current strength encourages tentacle extension - achieves greatest abundance in the most wave sheltered (but usually with significant tidal flow) areas	[6] [7] [1]
Use of cover	- no information found	
Biotic Factors		
Spawning time	- eggs & sperms released at intervals throughout year in north-east England	[8]
Spawning habitat	- reproduction can also occur via basal laceration	[1]
Eggs	- dispersal potential of >10,000 m and a colonization rate of 5-10 years - panulae spend months in plankton dispersing far from parents	[9] [9]
Foods	- passive suspension feeder on copepods, polychaete larvae, bivalve and gastropod veligers, copepod naupliii, and barnacle nauplii and cyprids - prefer barnacle cyprids, ascidian larvae and gammarid amphipods over over invertebrate eggs, foramaniferans, calanoid and harpacticoid copepods and ostracods.	[10] [1]
Other	- growth rate in laboratory: 9 cm/month - newly settled have growth rate of up to 0.6 mm and 0.8 mm in pedal diameter per day - winter predation by the sea slug, *Aeolida papillosa* can result in heavy mortality - aggressive colonizer, can grow over other earlier colonizers, larvae readily settles on new substrates - expected that life expectancy is > 10 yrs - loss of substratum will result in loss of population, however, re-colonization is rapid (within 2 to 3 yrs) - can withstand smothering by less than 5 cm sediment, will expand upwards to be above sediment - can produce mucus to clear itself of silt - low tolerance to desiccation: vulnerable & adversely affected - under laboratory conditions flow rates in excess of 70 cm/s caused tentacle withdrawal - do not appear to occur in very strong tidal flows (exceeding 5 knots) - decrease in flow rate likely to adversely affect food availability by reducing food transport - increased turbidity reduces algal growth and results in more substrate becoming available for colonization - strong wave action seems to result in increase in numbers but individuals remain small in size - physical impact of abrasion likely to cause damage and mortality to exposed individuals but, because the species habitually reproduces by basal laceration, it seems likely that torn individuals will re-grow - synthetic chemicals: intolerance is assessed as low specifically to TBT	[11] [12] [9] [9] [1] [1] [1] [1] [1] [13] [1] [1] [14] [15] [1] [16]

	- no records found of any mortality of *Metridium senile* during oil spills or of any experimental studies of effects	[1]
	- possible tolerance of pollution from a pulp mill (and increase in turbidity)	[14]

References

1. Hiscock, K. and E. Wilson, Metridium senile. *Plumose anemone. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2003, Marine Biological Association of the United Kingdom. [cited 8/11/2004]: Plymouth.
2. Braber, L. and C.H. Borghouts, *Distribution and ecology of Anthozoa in the estuarine region of the rivers Rhine, Meuse and Scheldt.* Hydrobiologia, 1977. **52**:15-21.
3. Shumway, S.E., *Activity and respiration of the sea anemone,* Metridium senile *(L.) exposed to salinity fluctuations.* J. Exp. Mar. Biol. Ecol., 1978. **33**: 85-92.
4. Wahl, M., *The recolonization potential of* Metridium senile *in an area previously depopulated by oxygen deficiency.* Oecologia, 1985. **67**: 255-259.
5. Wahl, M., *The fluffy sea anemone* Metridium senile *in periodically oxygen depleted surroundings.* Mar. Biol., 1984. **81**: 81-86.
6. Anthony, K.R.N., *Prey capture by the sea anemone* Metridium senile *(L.): effects of body size, flow regime, and upstream neighbors.* Biol. Bull. Woods Hole, 1997. **192**: 73-86.
7. Robbins, R.E. and J.M. Shick. *Expansion-contraction behavior in the sea anemone* Metridium senile*: environmental cues and energetic consequences.* In *Nutrition in the lower Metazoa: Meeting on Nutrition in the lower Metazoa, 11 Sep 1979.* 1980. Caen (France).
8. Bull, H.O., *The Anthozoa of the Cullercoats District.* In *Report of the Dove Marine Laboratory 3rd Series 6.* 1939, Dove Marine Laboratory: Dove. 29 pp.
9. Sebens, K.P., *Community ecology of vertical rock walls in the Gulf of Maine: small-scale processes and alternative community states.* Pages 346-371. In *The Ecology of Rocky Coasts: essays presented to J.R. Lewis, D.Sc.*, P.G. Moore and R. Seed, Editors. 1985, Hodder & Stoughton: London.
10. Purcell, J.E., *The diet of large and small individuals of the sea anemone* Metridium senile. Bull. South Calif. Acad. Sci., 1976. **76**(3): 168-172.
11. Bucklin, A., *Growth and asexual reproduction of the sea anemone* Metridium*: comparative laboratory studies of three species.* J. Exp. Mar. Biol. Ecol., 1987. **110**: 41-52.
12. Bucklin, A., *Biochemical genetic variation, growth and regeneration of the sea anemone,* Metridium, *of British shores.* J. Mar. Biol. Assoc. U. K., 1985. **65**: 141-157.
13. Hiscock, K., *Water movement.* Pages 58-96. In *Sublittoral ecology. The ecology of shallow sublittoral benthos*, R. Earll and D.G. Erwin, Editors. 1983, Clarendon Press: Oxford.
14. Svane, I. and F. Groendahl, *Epibioses of Gullmarsfjorden: an underwater stereophotographical transect analysis in comparison with the investigations of Gislen in 1926-29.* Ophelia, 1988. **28**: 95-110.

15. Bucklin, A., *Adaptive advantages of patterns of growth and asexual reproduction of the sea anemone* Metridium senile *(L.) in intertidal and submerged populations.* J. Exp. Mar. Biol. Ecol., 1987. **10**: 225-243.
16. Mercier, A., E. Pelletier, and J.-F. Hamel, *Response of temperate sea anemones to butyltin contamination.* Can. J. Fish. Aquat. Sci., 1998. **55**: 239-245.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Threadworm *Capitella capitata*	Source
Abiotic Factors		
Temperature	- relatively tolerant to an increase in temperature - low survival at low T & low salinity: 12 °C & 20 ‰ - combined temperature and salinity changes may decrease viability of populations	[1] [2] [2]
Salinity	- occurs in > 18 ‰ up to 40 ‰ - can withstand fluctuations & shows positive correlation with salinity - ↓salinity may affect longevity and abundance	[1] [3] [1]
Oxygen	- thrives in azoic sediments, tolerant of hypoxia - at 5-6°C about 50 % survival at 0.8-0.9 ml/l O_2 for 13 days & at 1.5ml/l most survived >24 days - will stop burrowing and feeding at < 0.8 ml/l O_2 - 100% mortality after 30 days at 1 mmHg	[1] [4] [1] [5]
Substrate preference	- occurs on muddy sand, gritty sand, fine sand or rich mud on the lower shore to sub-littoral	[1]
Water current and tides	- important larval transport to new areas of colonization	[6]
Cover	- may be found under pebbles or small stones, with the burrows at or near the surface of the sediment	[1]
Biotic Factors		
Reproduction time	- sexual maturity reaches at about age 3 to 4 months	[7]
Reproduction habitat	- same as living habitat, needs submersion	[1]
Reproduction	- 6-600 eggs per female in USA	[8]
General Traits	- earthworm-like appearance, lifespan 1 to 2 years - blood red in colour, 2 to 10 cm in length - growth rate of 30 mm/year - no-selective, subsurface feeder on micro-organisms, phytoplankton and detritus	[1] [1] [9] [7]
Other	- two to 4 weeks from eggs to juvenile stages - densities in polluted sites can more than double that in non-polluted sites (e.g. sewage polluted sites) - lugworms & juvenile densities negatively associated - loss of substratum results in loss of population but recovery can be very high - able to withstand about 5 cm of sediment deposition - suspended particles provide food and hence decrease in particles may have negative impact on food - infaunal habitat may be damaged by scallop dredges - presence of synthetic chemicals ↓ reproductive potential - fairly resistant to heavy metal contamination although viability of population may be decreased - Hg is more lethal than Cu, Cr, Zn, Cd and Pb - can withstand relatively high hydrocarbon concentrations	[10] [11] [12] [13] [1] [1] [1] [14] [15] [16] [1]

References

1. Riley, K., Capitella capitata. *Gallery worm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2002, Marine Biological Association of the United Kingdom. [cited 20/07/2004]: Plymouth.
2. Redman, C.M., *Effect of temperature and salinity on the life history of* Capitella capitata *(type I).* Dissertation Abstracts, 1985. **46**: 91 pp.
3. Soemodinoto, A., B.L. Oey, and H. Ibkar-Kramadibrata, *Effect of salinity decline on macrozoobenthos community of Cibeurum River estuary, Java, Indonesia.* Indian J. Mar. Sci., 1995. **24**: 62-67.
4. Rosenberg, R., *Benthic faunal recovery in a Swedish fjord following the closure of a sulphite pulp mill.* Oikos, 1972. **23**: 92-108.
5. Warren, L.M., *The ecology of* Capitella capitata *in British waters.* J. Mar. Biol. Assoc. U. K., 1977. **57**: 151-159.
6. Shull, D.H., *Mechanisms of infaunal polychaete dispersal and colonisation in an intertidal sandflat.* J. Mar. Res., 1997. **55**: 153-179.
7. Fauchald, J. and P.A. Jumars, *The diet of worms: a study of polychaete feeding guilds.* Oceanogr. Mar. Biol. Ann. Rev., 1979. **17**: 193-284.
8. Grassle, J.F. and J.P. Grassle, *Opportunistic life histories and genetic systems in marine benthic polychaetes.* J. Mar. Res., 1974. **32**: 253-284.
9. Warren, L.M., *A population study of the polychaete* Capitella capitata *at Plymouth.* Mar. Biol., 1976. **38**: 209-216.
10. Planas, M. and J. Mora, *Epigenetical changes in* Capitella *(Polychaeta, Capitellidae) in the Ensenada de Lourizan (NW Spain).* Vie Milieu, 1989. **39**: 159-163.
11. Perkins, E.J., *The biology of estuaries and coastal waters.* 1974, New York, New York: Academic Press. 678 pp.
12. Flach, E.C., *Disturbance of benthic infauna by sediment-reworking activities of the lugworm* Arenicola marina. Neth, J. Sea Res., 1991. **30**: 81-89.
13. Wildish, D.J. and M.L.H. Thomas, *Effects of dredging and dumping on benthos of Saint John Harbour, Canada.* Mar. Environ. Res., 1985. **15**: 45-57.
14. Schiff, K.C., *The effect and accumulation of sediment-adsorbed DDT in the polychaete,* Capitella capitata. Bull. Mar. Sci., 1991. **48**: 594.
15. Bryan, G.W., *Pollution due to heavy metals and their compounds*. Pages 1289-1431. In *Marine Ecology: A Comprehensive, Integrated Treatise on Life in the Oceans and Coastal Waters*, O. Kinne, Editor. 1984, John Wiley & Sons: New York.
16. Reish, D.J., *The effects of heavy metals on polychaetous annelids.* Revue Internationale d'Oceanographie Medicale, 1978. **49**: 99-104.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Ragworm *Hediste diversicolor* (formerly in *Nereis)*	Source
Abiotic Factors		
Temperature	- increase during spring (between 6 and 11 °C) encourages maturation and spawning	[1]
Salinity	- can withstand great salinity variations down to 5 psu - widespread in brackish waters, euryhaline - < 8 psu can have adverse effect on reproduction	[2] [1] [1]
Oxygen	- survives very low O_2 conditions (hypoxia for 5 days) - 15% mortality for 22 days at 10% O_2	[3] [4]
Substrate preference	- restricted to littoral zone in mud or sand in fairly permanent U-shaped mucous burrow	[3]
Water current and tides	- important in food transport to individuals - may assist in swimming to new areas for colonisation - larvae may be tidally dispersed over 3 km - moderately strong currents may removed sediments suitable for habitat	[1] [1] [1] [1]
Cover	- uses U-shaped burrows to hide from predators	[1]
Biotic Factors		
Reproduction time	- early spring (increase in temperature) and spawning coincides with new or full moon	[5]
Reproduction habitat	- males crawl around in search of females, depositing sperms directly outside female burrow - females perform intense ventilation movements to get sperms into burrows, fertilized eggs remain in burrows - both sexes die shortly after spawning	[1] [1] [1]
Reproduction	- dioecious, males may be lower in numbers than females (less than 10%) in some areas - eggs extremely resistant to environmental conditions	[5] [5]
General Traits	- dioecious, sexes extremely indistinguishable - reddish brown in summer & fall, bright green in spring - feeds on surface particles near burrow and suspension feeding on water passing through the burrow - omnivorous, exhibits a diversity of feeding modes; carnivory, scavenging, filter feeding on suspended particles and deposit-feeding - can satisfy metabolic requirements from phytoplankton by filter-feeding at >1-3 μmg chlorophyll *a*/l - adults may reach 6 to 12 cm in length & mature between 1 to 3 yrs	[5] [5] [3] [1] [6],[7] [1]
Other	- slow development, larvae develop in mud, no true pelagic phase - adult mode is assumed by larvae at 10 weeks - can withstand smothering by several inches of sand - uptake of heavy metals is via sediment ingestion	[5] [5] [8] [9]

References

1. Budd, G.C., Hediste diversicolor. *Ragworm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2001, Marine Biological Association of the United Kingdom. [cited 8/11/2004]: Plymouth.
2. Perkins, E.J., *The biology of estuaries and coastal waters*. 1974, New York, New York: Academic Press. 678 pp.
3. Wells, G.P. and R.P. Dales, *Spontaneous activity patterns in animal behaviour: the irrigation of the burrow in the polychaetes* Chaetopterus variopedatus *Renier and* Nereis diversicolor *O.F. Muller*. J. Mar. Biol. Assoc. U. K., 1951. **29**: 661-680.
4. Diaz, R.J. and R. Rosenberg, *Marine benthic hypoxia: a review of its ecological effects and the behavioural responses of benthic macrofauna.* Oceanogr. Mar. Biol. Ann. Rev., 1995. **33**: 245-303.
5. Dales, R.P., *The reproduction and larval development of* Nereis diversicolor. J. Mar. Biol. Assoc. U. K., 1951. **29**: 321-359.
6. Nielsen, A.M., et al., *Feeding, growth and respiration in the polychaetes Nereis* diversicolor *(facultative filter-feeder) and* Nereis virens *(omnivorous) - a comparative study.* Mar. Ecol. Prog. Ser., 1995. **125**: 149-158.
7. Riisgård, H.U., *Filter-feeding in the polychaete* Nereis diversicolor*: a review.* Neth, J. Aquat. Ecol., 1994. **28**: 453-458.
8. Smith, J.E., *Salinity variation in interstitial water of sand at Kames Bay, Millport, with reference to the distribution of* Nereis diversicolor. J. Mar. Biol. Assoc. U. K., 1955. **34**: 33-46.
9. Wang, W.-X., I. Stupakoff, and N.S. Fisher, *Bioavailability of dissolved and sediment-bound metals to a deposit-feeding polychaete.* Mar. Ecol. Prog. Ser., 1999. **178**: 281-293.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Two–gilled bloodworm, beakworm, beak-thrower *Glycera dibranchiata*	Source
Abiotic Factors		
Temperature	- bloodworm production and mean annual temperature are inversely related - water temperature >13 °C, mud at 14 °C for spawning	[1] [2]
Salinity	- no published data but worms are osmo-conformers - can equilibrate to 50% and 150% seawater in 10-25 hrs	[1] [3]
Oxygen	- haemoglobin is in coelomic cavity: no vascular system - no data on minimum dissolved O_2 needed for survival	[1],[4] [1]
Substrate preference	- occupy burrows in low water out to about 400 m in mud, sand, gravel & seagrass beds - most abundant in fine muds with high organic content	[1] [4],[2]
Water current and tides	- swarming occurs during spawning at high tide	[2]
Use of cover	- occupy burrows	[1]
Biotic Factors		
Spawning time	- in Maine and southwest Nova Scotia from mid-May to early June - populations from Maryland reproduce in the fall and possibly late spring (biannually) - sexual forms (epitokes) swarm in shallow water over a period of 1 to 3 days at high tide in the afternoon - males emit sperms while swimming, females rupture & release up to 10 million eggs/individual - developed sperms give males creamy colour, while developed eggs give females pale brown colour	[4] [5] [5],[2] [2] [4]
Spawning habitat	- dioecious, gametogenesis occurs in the undivided coelom and requires about 1 yr - undergo radical morphological changes before reproduction: atrophy of musculature and alimentary tract, elongation of parapodia and setae - in intertidal populations gametogenesis begins late summer - most reproduce & die at age 3 yrs, some at 4 & 5 yrs	[5] [5] [4] [1],[4]
Eggs	- released into the coelom when ~21 µm in diameter - discoidal; mature eggs are 151-160 µm in diameter - early larval development occurs on sediment surface, proceeding to swimming stage in 14 to 20 hrs after fertilization - larvae not found in plankton: short planktonic life or demersal larvae	[1],[2] [1],[2] [5] [1]
Foods	- predator/deposit feeder/scavenger; feeds on amphipods and polychaetes and dead organic matter - likely that detritovory is manifested only in absence of suitable animal material - prey detected by mechano-reception and ambushed at sediment surface - can utilise dissolved organic matter	[1] [1] [1] [1]
Other	- bright pink and have a pair of enlarged gills above and	[1]

	below each of the middle parapodia	
	- have proboscis armed with neurotoxin-injecting jaws	[1]
	- important baitworm fishery in the Maritimes	[4]
	- over-harvesting of mudflats is a problem in some areas (e.g. in Maine)	[1]
	- maximum life span of 5 yrs, maximum length: 37 cm	[4],[2]
	- rapid growth during second and third yrs, little or no growth occurs during summer	[1],[4]
	- black-bellied Plover (*Pluvialis squatorola*) specializes in preying on the bloodworm	[6]
	- worms are conspicuous in the water column during fall & winter probably searching for more suitable habitat	[1]
	- in contaminated sites copper accumulates in the jaws	[7]
	- cadmium accumulates through body surface & intestines	[8]
	- rapidly uptakes mercury: 2 hr to reach 75% equilibrium	[9]
	- worms die after spawning and presence of spent individuals may be used to detect populations & timing of spawning	[4]

References

1. Wilson Jr., W.H. and R.E. Ruff, *Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic)--sandworm and bloodworm.* U.S. Fish. Wildl. Serv. Biol. Rep, 1988. 82(11.80) U.S. Army Corps of Engineers, TR EL-82-4.: 1-23.
2. Creaser Jr., E.P., *Reproduction of the bloodworm (*Glycera dibranchiata*) in the Sheepscot Estuary, Maine.* J. Fish. Res. Bd. Can., 1973. **30**: 161-166.
3. Machin, J., *Osmotic responses of the bloodworm* Glycera dibranchiata *Ehlers: a graphical approach to the analysis of weight regulation.* Comp. Biochem. Physiol. (A), 1975. **52**: 49-54.
4. Klawe, W.L. and L.M. Dickie, *Biology of the bloodworm,* Glycera dibranchiata *Ehlers, and its relation to the bloodworm fishery of the Maritime Provinces.* Bulletin (Fish. Res. Bd. Can.), 1957. **115**: 1-37.
5. Simpson, M., *Reproduction of the polychaete* Glycera dibranchiata *at Solomons, Maryland.* Biol. Bull. Woods Hole, 1962. **123**: 396-411.
6. Dubois-Laviolette, A.G.T.M., *Foraging and energetics of the Black-bellied Plover* Pluvialis squatarola *(Linnaeus) and related aspects of its prey* Glycera dibranchiata *Ehlers on the Starrs Point mudflat, Minas Basin, N.S.*, Thesis in Biology. 1985, Acadia University: Wolfville, Nova Scotia. 150 pp.
7. Gibbs, P.E. and G.W. Bryan, *Copper--the major metal component of glycerid polychaete jaws.* J. Mar. Biol. Assoc. U. K., 1980. **60**: 205-219.
8. Rice, M.A. and P.K. Chien, *Uptake, binding and clearance of divalent cadmium in* Glycera dibranchiata *(Annelida: Polychaeta).* Mar. Biol., 1979. **53**: 33-39.
9. Medeiros, D.M., L.L. Caldwell, and R.L. Preston, *A possible physiological uptake mechanism of methylmercury by the marine bloodworm (*Glycera dibranchiata*).* Bull. Environ. Contam. Toxicol., 1981. **24**: 97-101.

Species Life Requirements/Habitats: Musquash Estuary (after [1])		
Species	Common periwinkle *Littorina littorea*	Source
Abiotic Factors		
Temperature	- point of heat coma: 39 °C - adults can easily tolerate sub-zero temperatures and the freezing of over 50 % of their extracellular body fluids	[2] [3]
Salinity	- fairly tolerant of brackish water - found in 18 to 40 ‰ - tolerant of full, variable and reduced salinities	[3] [4] [4]
Oxygen	- can tolerate long periods of oxygen deprivation by reducing metabolic rate down to 20% of normal	[5]
Substrate preference	- lower parts of rocky and gravely shores and among eelgrass in some salt marshes - upper shore into the sublittoral - in sheltered conditions n sandy or muddy habitats such as estuaries and mudflats	[4] [3] [3]
Water current and tides	- important for egg and larval dispersal	[3]
Use of cover	- may hide in crevices and under intertidal seaweeds during exposure	[4]
Biotic Factors		
Spawning time	- dependent on climatic conditions but can be throughout year - in estuaries spawning occurs in January - males select larger more fecund females to breed with	[4] [4] [4]
Spawning habitat	- sexes separate, fertilization internal - egg release synchronized with spring tides on several separate occasions	[4] [4]
Eggs	- laid in saucer-like capsules (up to 9 eggs/capsule, eggs 1 mm across) floating in water column - fecundity increases with size and up to 100,000 eggs/year can be produced - hatches into larvae which settles unto shore (this can take up to 6 weeks)	[4] [4] [3]
Foods	- herbivore, feeds on a range of fine green, brown and red algae, including *Ulva lactuca*, *Cladophora* spp. & *Ectocarpus* spp.	[4]
Other	- largest of the Littorinid species - maturity is reached at between 10-12mm shell height - can live for up to 4 years - more active when submerged - growth rate of 0.065-0.097 mm/day - parasitism can cause sterility - loss of substratum will result in loss of population since mobility is low - smothering by sediment will result in death - silt build up will result in slow lost of habitat - has good ability to withstand desiccation - increased wave exposure may cause dislodgement and damage	[4] [4] [4] [4] [4] [4] [3] [3] [3] [3] [3]

	- tolerant of high TBT levels, but strong toxicities may result in low reproductive ability	[3],[6]
	- suggested as a suitable bioindicator species for some heavy metals in the marine environment because of its heavy metal tolerance	[7]
	- highly intolerant of hydrocarbon pollution	[3]
	- increased flow rates (> 6 knots) can dislodge snails	[3]
	- changes in turbidity not likely to have any direct effects	[3]
	- abrasion can result in damage to shell which increases the chance of desiccation and successful predation	[3]

References

1. Parker, M.A. and R.J. Rutherford, *Musquash Ecosystem Framework Development*. 2003, East Coast Aquatics & Thaumas Environmental: Dartmouth, Nova Scotia. 39 pp.
2. Perkins, E.J., *The biology of estuaries and coastal waters*. 1974, New York, New York: Academic Press. 678 pp.
3. Jackson, A., Littorina littorea. *Common periwinkle. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2002, Marine Biological Association of the United Kingdom. [cited 20/07/2004]: Plymouth.
4. Davis, D.S., *Periwinkles*. 1971, Halifax, NS: Nova Scotia Museum. 7 pp.
5. MacDonald, J.A. and K.B. Storey, *Cyclic AMP-dependent protein kinase: role in anoxia and freezing tolerance of the marine periwinkle* Littorina littorea. Mar. Biol., 1999. **133**: 193-203.
6. Deutsch, U. and P. Fioroni, *Effects of tributyltin (TBT) and testosterone on the female genital system in the mesogastropod* Littorina littorea *(Prosobranchia)*. Helgolander Meeresuntersuchungen, 1996. **50**: 105-115.
7. Bryan, G.W., *Pollution due to heavy metals and their compounds*. Pages 1289-1431. In *Marine Ecology: A Comprehensive, Integrated Treatise on Life in the Oceans and Coastal Waters*, O. Kinne, Editor. 1984, John Wiley & Sons: New York.

Species Life Requirements/Habitats: Musquash Estuary (after [1])		
Species	Smooth/dwarf/flat periwinkle *Littorina obtusata*	Source
Abiotic Factors		
Temperature	- can withstand wide variances in temperature - ability for near instantaneous suppression of metabolic rate and entrance into short-term metabolic diapause at temperatures above 20-35 °C	[2] [3]
Salinity	- tolerant of low salinities and a wide range of exposure	[4]
Oxygen	- no information found	
Substrate preference	- among rocks and under rockweeds in middle shore - saltwater intertidal areas in shallow water on rocks or other hard surfaces, although specimens can be found above high-tide mark	[5] [2]
Water current and tides	- no information found	
Use of cover	- hides among rocks and under rockweeds	[5]
Biotic Factors		
Spawning time	- no information found	
Spawning habitat	- internal fertilization, sperms can be stored for short periods of time but can survive for up to three months - females can mate many times before fertilization	[2] [2]
Eggs	- whitish oval or kidney shaped gelatinous egg masses laid under rockweed and sometimes on rock surfaces - laid in bunches of 50-150 eggs on fucoid algae - embryos development into snails in about 4 weeks	[5] [2] [5],[4]
Foods	- herbivore, feeds on algae, such as *Fucus spiralis, F. vesiculosis, F. seratus* and *Ascophyllum nodosum* - feeding during high tide or in wet conditions	[2] [2]
Other	- females are larger than males - hardy survivors in environments of constant change	[2] [2]

References

1. Parker, M.A. and R.J. Rutherford, *Musquash Ecosystem Framework Development*. 2003, East Coast Aquatics & Thaumas Environmental: Dartmouth, Nova Scotia. 39 pp.
2. Roma, J., M.L. Oetelaar, and B.W. Barkhose, *Marine Invertebrate Diversity Initiative (online):* Littorina obtusata*: http://www.fundyforum.com/MIDI/*. 2004.
3. McMahon, R.F., W.D. Russell-Hunter, and D.W. Aldridge. *Lack of metabolic temperature compensation in the intertidal gastropods,* Littorina saxatilis *(Olivi) and* L. obtusata *(L.).* In *Advances in Littorinid Biology:* Hydrobiologia, vol. 309. 1995. Roscoff (France), 19-25 Sep 1993.
4. Pizzolla, P.F., Littorina obtusata. *Common flat periwinkle. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2004, Marine Biological Association of the United Kingdom. [cited 10/08/2004]: Plymouth.
5. Davis, D.S., *Periwinkles*. 1971, Halifax, NS: Nova Scotia Museum. 7 pp.

Species Life Requirements/Habitats: Musquash Estuary (after [1])		
Species	Rough periwinkle *Littorina saxatilis*	Source
Abiotic Factors		
Temperature	- coma in air at 34 °C - coma in water at 40 °C - death in air 32 °C - death in water 40 °C	[2] [2] [2] [2]
Salinity	- no specific data found to date	
Oxygen	- throughout the temperature range of 22-42 °C the respiratory rates in air were higher than in water - can survive by air breathing	[2] [3]
Substrate preference	- common on high rocky shores and salt marsh ponds	[4]
Water current and tides	- no information found	
Use of cover	- moves into deepest crevices for protection from hot or cold conditions	[4]
Biotic Factors		
Spawning time	- no information found	
Spawning habitat	- no information found	
Eggs	- fertilized in the oviduct of the female - sexes separate and viviparous (produce live young not eggs)	[4] [5]
Foods	- feeds on *Calothrix*, the bluegreen algae of the black zone	[3]
Other	- smallest of the Littorinid species	[3]

References

1. Parker, M.A. and R.J. Rutherford, *Musquash Ecosystem Framework Development*. 2003, East Coast Aquatics & Thaumas Environmental: Dartmouth, Nova Scotia. 39 pp.
2. Sandison, E.E., *Respiratory response to temperature and temperature tolerance of some intertidal gastropods*. J. Exp. Mar. Biol. Ecol., 1967. 1: 271-281.
3. Berrill, M. and D. Berrill, *The North Atlantic Coast: A Sierra Club Naturalist's Guide*. 1981, San Francisco: Sierra Clob Books. 464 pp.
4. Davis, D.S., *Periwinkles*. 1971, Halifax, NS: Nova Scotia Museum. 7 pp.
5. Gosner, K.L., *A Field Guide to the Atlantic Seashore*. 1978, Boston: Houghton Miffin Company. 309 pp.

Species Life Requirements/Habitats: Musquash Estuary (after [1])		
Species	Baltic/Little macoma *Macoma balthica*	Source
Abiotic Factors		
Temperature	- ambient temperature range 10-14 °C - range 0-10 °C best for growth - wide tolerance for temperature variation - greater than 49 °C thermal numbing of gill cilia followed by death occurs	[2] [3] [4] [5]
Salinity	- in waters > 0.4 ‰ - in salinities as low as 5 ‰ - found in fully saline to brackish waters - survived > 150 days at 30.5 ‰ - long-term decrease salinity may result in ↓ growth	[6] [4] [5] [7] [7]
Oxygen	- very tolerant of low oxygen - under low within sediment O_2 will move to surface - LT_{50} under anoxic conditions: 50 - 70 days at 5°C, 30 days at 10°C, 25 days at 15°C and 11 days at 20°C	[6] [8] [9]
Substrate preference	- sand, mud & muddy sand in estuaries & tidal flats - buried up to 3 to 8 cm in sand or mud, intertidal to > 30 m (up to 190 m in the Baltic Sea)	[5] [10]
Water current and tides	- prefers moderately strong to weak currents - important in gamete & larval distribution ~10 km	[5] [5]
Use of cover	- makes tubes	[10]
Biotic Factors		
Spawning time	- April to end of May in Europe, spring or fall	[2]
Spawning habitat	- spawns into the water column	[5]
Eggs	- 10,000-100,000 eggs/female - 17 mm shell length female estimated to expel between 10,000 and 50,000 eggs.	[5] [5]
Foods	- facultative filter-feeder and surface deposit-feeder - suspended phytoplankton, diatoms, deposited plankton, detritus & bacteria	[11],[12] [5]
Other	- mean growth rate 3.3 mm/yr, mean length 18-20 mm - sexual maturity at sizes > 6 mm (10 to 22 months) - life span typically 5 to10 yrs but can live up to 30 yrs in deep, cold water - substratum loss will result in loss of population - high sensitivity to synthetic compounds, heavy metals and hydrocarbons - not likely to be smothered by < 5 cm of sediment - can transfer toxicants through food chain to predators - increased suspended sediment may encourage suspension feeding and indirectly reduce vulnerability to siphon predation - tolerant to desiccation: tight closure of shells & by staying buried in high water content sediment - increased flow rates will re-suspend sediments & cause erosion of habitat and may result in mortality to some individuals	[13] [14] [13] [5] [5] [5] [15] [5] [5] [5]

	- fairly tolerant of displacement resulting in exposure: can rebury within 17 mins, however, during this time increased risk of predation	[16]
	- suggested as a potential indicator organism of organic pollution because the species was reported to increase in abundance towards the sources of nutrient enrichment & to disappear when the organic loading became heavier	[5]

References

1. Parker, M.A. and R.J. Rutherford, *Musquash Ecosystem Framework Development*. 2003, East Coast Aquatics & Thaumas Environmental: Dartmouth, Nova Scotia. 39 pp.
2. Wenne, R., *Microgeographic differentiation in condition and biochemical composition of* Macoma balthica *(L.) from Gadansk Bay (South Balthic), and the relationship bewteen this cycle and energy reserve changes*. Pol. Arch. Hydrobiol., 1985. **32**: 47-63.
3. de Wilde, P.A.W.J. *Influence of temperature on behaviour, energy metabolism and growth of* Macoma balthica *(L.)*. In *9th European Marine Biology Symposium*. 1975. Oban, Scotland: Aberdeen University Press.
4. Gosner, K.L., *A Field Guide to the Atlantic Seashore*. 1978, Boston: Houghton Miffin Company. 309 pp.
5. Budd, G.C. and W.J. Rayment, Macoma balthica. *Baltic tellin. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2001, Marine Biological Association of the United Kingdom. [cited 15/03/2004]: Plymouth.
6. Wenne, R. and E. Styczynska-Jurewicz, *Microgeographic differentiation in condition and biochemical composition of* Macoma balthica *(L.) from Gadansk Bay (South Balthic)*. Pol. Arch. Hydrobiol., 1985. **32**: 194-197.
7. McLusky, D.S. and D.G. Allan, *Aspects of the biology of* Macoma balthica *(L.) from the estuarine Firth of Forth*. J. Moll. Studies, 1976. **42**: 31-45.
8. Brafield, A.E. and G.E. Newell, *The behaviour of* Macoma balthica *(L.)*. J. Mar. Biol. Assoc. U. K., 1961. **41**: 81-87.
9. Dries, R.R. and H. Theede, *Sauerstoffmangelresistenz mariner Bodenvertebraten aus der West-lichen Ostsee*. Mar. Biol., 1974. **25**: 327-332.
10. Pollock, L.W., *A practical guide to the marine animals of northeastern North America*. 1998, New Brunswick, N.J.: Rutgers University Press. x + 367 pp.
11. Berrill, M. and D. Berrill, *The North Atlantic Coast: A Sierra Club Naturalist's Guide*. 1981, San Francisco: Sierra Clob Books. 464 pp.
12. Green, R.H., et al., *An arctic intertidal population of* Macoma balthica *(Mollusca, Pelecypoda): genotypic and phenotypic components of population structure*. Can. J. Fish. Aquat. Sci., 1983. **40**: 1360-1371.
13. Gilbert, M.A., *Growth rate, longevity and maximum size of* Macoma balthica *(L.)*. Biol. Bull. Woods Hole, 1973. **145**: 119-126.

14. Harvey, M. and B. Vincent, *Spatial and temporal variations of the reproduction cycle and energy allocation of the bivalve* Macoma balthica *(L.) on a tidal flat.* J. Exp. Mar. Biol. Ecol., 1989. **129**: 199-217.
15. Bull, K.R., et al., *Alkyl lead pollution and bird mortalities on the Mersey Estuary, UK.* Environ. Poll. (A), 1983. **31**: 239-259.
16. McGreer, E.R., *Sublethal effects of heavy metal contaminated sediments on the bivalve* Macoma balthica *(L.).* Mar. Poll. Bull., 1979. **10**: 259-262.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Soft-shelled clam *Mya arenaria*	Source
Abiotic Factors		
Temperature	- survives in 6 to 14 °C - optimal laboratory larval growth 17 to 23 °C - critical spawning at 10 to 12 °C - spawning peak of 4 to 6 °C in Massachusetts	[1] [2] [3] [4]
Salinity	- can survive in down to 5 ppt but best at 25 to 35 ppt, however, temperature and size dependent - mortalities high at < 2 ppt	[1],[5] [5]
Oxygen	- O_2 intake independent of oxygen concentration down to about 2.8 mg/litre, greatest at 20 °C - can function as facultative anaerobes - can tolerate low O_2 and H_2S for several weeks	[5] [5] [6]
Substrate preference	- bays and estuaries, intertidally and subtidally, to depths of about 9 m - soft mud, sand, compact clays, course gravels, and between stones	[1] [1]
Water current and tides	- important in spawning and the distribution of gametes and planktonic larvae (dispersal potential > 10 km) - water is needed for suspension feeding - currents carry away possible smothering blanket of silt	[1] [1] [5] [5]
Use of cover	- live in burrows, adults can burrow to 30 cm	[1]
Biotic Factors		
Spawning time	- June to September depending on water temperature and food availability - sexually mature around 20 mm shell length - males usually spawn first, stimulating females	[7] [5] [5]
Spawning habitat	- gametes released into water column	[1]
Eggs	- 100,000 to1,000,000, 1 to 5,000,000 eggs released/individual - 66 µm, white, gelatinous - estimated 0.1% of egg production survived to successful settlement	[6] [5] [8]
Foods	- suspension feeder on microscopic plants and animals (algae, diatoms, algal fragments and naked flagellates) - up to 54 litres of water may be filtered/day by each clam	[1] [1]
Other	- long siphon that cannot be completely retracted into the shell - separate sexes, larvae planktonic from 2 to several weeks - after metamorphosis, juvenile settles and attaches via byssal threads until 6 to 13 mm when they move about and eventually burrow - grows rapidly in first 4 to 5 yrs, grow ~3.0 cm/yr, larger animals grow ~0.9 cm/yr	[9] [9] [10] [1]

	- smaller clams more capable of re-burrowing after disturbance than larger clams	[11]
	- life span 10 to 20 yrs, maximum 28 yrs reported	[11],[12]
	- bacteria and viruses from municipal effluent can accumulate in the clam's body tissues posing a threat to human health	[5]

References

1. Hawkins, C.M., *Underwater World: The Soft-shell Clam.* 1985, Communications Directoriate, D.F.O, Canada: Ottawa, ON.
2. Stickney, A.P., *Salinity, temperature, and food requirements of soft shelled clam larvae in laboratory culture.* Ecology, 1964. 45: 283-291.
3. Nelson, T.C., *On the distribution of critical temperatures for spawning and for ciliary activity in bivalve molluscs.* Science, 1928. 67: 220-221.
4. Brousseau, D.J., *Spawning cycle, fecundity, and recruitment in a population of soft-shell clam,* Mya arenaria *from Cape Ann, Massachusetts.* U.S. Fish. Bull., 1978. 76: 155-166.
5. Newell, C.R. and H. Hidu, *Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic) -- softshell clam.* U.S. Fish Wildl. Serv. Biol. Rep., 1986. 82(11.53) U.S. Army Corps of Engineers, TR EL-82-4.: 17 p.
6. Strasser, M., Mya arenaria *- an ancient invader of the North Sea coast.* Helgoländer Meeresuntersuchungen, 1999. 52: 309-324.
7. Hawkins, C.M., *Environmental Habitat Quality Requirements: Guidelines for the Soft-Shelled Clam,* Mya arenaria. 1994, Habitat Planning, D.F.O.: Maritimes Region.
8. Brousseau, D.J., *Population dynamics of the soft-shell clam* Mya arenaria. Mar. Biol., 1978. 50: 67-71.
9. Gillespie, G.E. and A.R. Kronlund, *A Manual for Intertidal Clam Surveys.* Can. Tech. Rep. Fish. Aquat. Sci., 1999. **2270**: x + 144 pp.
10. Associates, W.G., *A five year soft-shell clam management and enhancement program for southwestern New Brunswick.* 1988, Prepared for Fisheries and Oceans Canada: Fredericton, N.B. xi + 101 pp.
11. Pfitzenmeyer, H.T. and K.G. Drobeck, *Some factors influencing reburrowing activity of soft-shell clam,* Mya arenaria. Chesapeake Science, 1967. **8**: 193-199.
12. MacDonald, B.A. and M.L.H. Thomas, *Age determination of the soft-shell clam* Maya arenaria *using shell internal growth lines.* Mar. Biol., 1980. **58**: 105-109.

Species Life Requirements/Habitats: Musquash Estuary (after [1])		
Species	Blue mussel *Mytilus edulis*	Source
Abiotic Factors		
Temperature	- minimum temperature for spawning 12 °C	[1]
	- lower lethal 5 °C inferred from larval no growth	[2]
	- no growth at 5 °C best between 10-16 °C, retarded at higher temperatures	[1]
	- optimal larval growth at 20 °C and 25-35 ppt	[3]
	- optimal temperature for growth 10-20 °C	[1]
	- upper tolerance limit about 26 °C	[1]
	- upper lethal temperature 27-29 °C	[4]
	- growth can take place at 3-25 °C	[1]
	- average lethal point 40-4-40.8 °C	[1]
	- young mussels (20-26 mm shell length) grow in 20-25 °C	[5]
	- young less cold tolerant than adults	[2]
	- lower lethal > -10 °C	[6]
	- adult median lethal temperature -12.5 to -20 °C with juveniles less cold tolerant than adults -8.0 to -12.5 °C	[2]
Salinity	- optimal larval growth at 20 °C and 25-35 ppt	[3], [1]
	- > 15 ppt required for successful fertilization	[1]
	- no growth at 19 ppt	[1]
	- retarded growth at 24 ppt	[1]
	- normal growth at 30-32 ppt	[1]
	- growth at 14 ppt	[1]
	- reduction of growth in salinities > 40 ppt	[1]
	- at 4-5 ppt very low growth rates	[1]
Oxygen	- survived 35 days at 10 °C with O_2 at 0.15 ml per litre	[3], [1]
	- if O_2 drops below 60% saturation, unable to compensate, O_2 uptake declines rapidly with change in ambient O_2 concentration	[3]
	- resistant to severe hypoxia, adults exhibit high tolerance of anoxia	[7]
Substrate preference	- attaches to a variety of hard substrates including rocks, stones, dead shells, compact mud	[1]
	- upper distribution limit primarily a function of the operation of physical factors (exposure to air, desiccation especially for the young stages, and may be genetics)	[1]
Water current and tides	- aid for dispersion of larvae and post-larvae	[3],[2]
	- marked increase in O_2 consumption with currents increasing from 0.0 to 0.1 m/sec	[1]
	- decrease in water flow is likely to decrease food availability	[2]
Use of cover	- commonly found under rockweed with which it competes for space in the intertidal	[1]
Biotic Factors		
Spawning time	- mid-June to mid-September (primarily August) St.	[8]

	Andrews, NB - no difference in spawning time between mussels permanently submerged & those periodically exposed to air	[1]
Spawning habitat	- spawns into open water, sexes separate	[3]
Eggs	- benthic, 60 to 90 µm in diameter	[9]
	- female (ca 7mm) can produce 7 to 8 million eggs, larger individuals may produce up to 40 million eggs	[10]
Foods	- suspension feeder on microplankton, bacteria and bits of organic material	
Other	- no present commercial cultivation in Bay of Fundy	[3]
	- in optimal conditions can grow to 60 to 80 mm in length within 2 years but in the high intertidal growth is significantly lower, and mussels may take 15 to 20 years to reach 20 -30 mm in length	[11]
	- predation is the single most important source of mortality	[2]
	- predators include dogwhelks, flounders, starfishes, crabs, eiders and herring gulls	[2]
	- growth rate affected by temperature, salinity, food availability, tidal exposure, intraspecific competition for space and food, and parasitism	[2]
	- fouling organisms may restrict feeding currents and lower the fitness of individual mussels	[2]
	- may accumulate faecal and pathogenic bacteria and viruses, and toxins from toxic algal blooms	[2]
	- loss of substratum results in loss of population	[2]
	- mussels are able to move upwards through accumulated sediment, but that a proportion will succumb to smothering	[2]
	- relatively tolerant of turbidity and siltation	[12]
	- increased emergence will expose mussel populations to increased risk of desiccation & increased vulnerability to extreme temperatures, potentially reducing their upper limit on the shore, & reducing their extent in the intertidal	[2]
	- synthetic contaminant accumulates in tissues and can induce mortality hence a proportion of the population may be lost	[2]
	- relatively tolerant of heavy metal contamination	[2]
	- hydrocarbon tissue burden results in decreased scope for growth & in some circumstances may result in mortalities, reduced abundance or distribution	[2]
	- heavy metals accumulate in tissues and can induce mortality	[2]

References

1. Parker, M.A. and R.J. Rutherford, *Musquash Ecosystem Framework Development*. 2003, East Coast Aquatics & Thaumas Environmental: Dartmouth, Nova Scotia. 39 pp.

2. Tyler-Walters, H., Mytilus edulis. *Common mussel. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line].* 2002, Marine Biological Association of the United Kingdom. [cited 16/09/2004]: Plymouth.
3. Newell, R.I.E., *Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North and Mid-Atlantic) -- blue mussel.* U.S. Fish Wildl. Serv. Biol. Rep., 1989. 82 (11.102) US Army Corps pf Engineers TR E1-82-4: 25 pp.
4. Almada-Villela, P.C., J. Davenport, and L.L.D. Gruffydd, *The effects of temperature on the shell growth of young* Mytilus edulis *L.* J. Exp. Mar. Biol. Ecol., 1982. **59**: 275-288.
5. Incze, L.S. and R.A. Lutz, *Mussel Culture: An East Coast Perspective*, In *Mussel Culture and Harvest: A North American Perspective*, R.A. Lutz, Editor. 1980, Elsevier Scientific Publishing Company: New York. 350 pp.
6. Williams, R.J., *Freezing tolerance in Mytilus edulis.* Comp. Biochem. Physiol., 1970. **35**: 145-161.
7. Diaz, R.J. and R. Rosenberg, *Marine benthic hypoxia: a review of its ecological effects and the behavioural responses of benthic macrofauna.* Oceanogr. Mar. Biol. Ann. Rev., 1995. **33**: 245-303.
8. Battle, H.I., *Rhythmical sexual maturity and spawning of certain bivalve molluscs.* Contrib. Can. Biol. Fish., NS., 1932. **7**: 257-276.
9. Lutz, R.A. and M.J. Kennish, *Ecology and morphology of larval and early larval postlarval mussels.* Pages 53-85. In *The mussel Mytilus: ecology, physiology, genetics and culture*, E.M. Gosling, Editor. 1992, Elsevier Science Publ: Amsterdam.
10. Thompson, G.B., *Distribution and population dynamics of the limpet* Patella aspera *(Lamarck) in Bantry Bay.* J. Exp. Mar. Biol. Ecol., 1979. **40**: 115-135.
11. Seed, R. and T.H. Suchanek, *Population and community ecology of* Mytilus. Pages 87-169. In *The mussel Mytilus: ecology, physiology, genetics and culture*, E.M. Gosling, Editor. 1992, Elsevier Science Publ.: Amsterdam.
12. Moore, P.G., *Inorganic particulate suspensions in the sea and their effects on marine animals.* Oceangr. Mar. Biol. Ann. Rev., 1977. **15**: 225-363.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Sea scallop *Placopecten magellanicus*	Source
Abiotic Factors		
Temperature	- larvae viable at 12 to 18 °C (lethal at higher)	[1]
	- maximal growth at 10 to 15 °C, lethal at 21 °C	[2]
	- spawning at 9 to 11.2 °C	[3]
Salinity	- lethal at < 16.5 ppt for adults	[2]
Oxygen	- no data found	
Substrate preference	- larvae are pelagic for over a month	[4]
	- larvae settle on gravely sand cover with biofilm	[5]
	- juveniles on gravel, small rocks, shells & silt	[6] [6]
	- adults on coarse substrate: gravel, shells, rock	
Water current and tides	- important for larval dispersion (6-25 cm/s)	[1]
	- when swimming can be carried long distances by currents	[7]
	- currents are important in transporting food to scallops	[1]
Use of cover	- no information found	
Biotic Factors		
Spawning time	- from late July to November in Bay of Fundy	[8]
	- August and September in the Gulf of Maine	[9]
Spawning habitat	- coarse substrate: gravel, shells, rock	[6]
Eggs	- average diameter 66.8 ± 1.6 μm	[10]
	- after fertilization eggs remain on sea floor	[1]
	- estimated 1 to 270 million eggs/individual	[10]
	- greater numbers from individuals in shallow (10-20 m)	[11]
Foods	- opportunistic suspension filter feeders on phytoplankton, diatoms, and microscopic animals	[1]
	- detrital particles and bacteria	[1]
	- seaweed detritus may be important in nearshore areas	[12]
Other	- settlement of spat assumed to occur by mid-December	[13]
	- spat and juveniles attach to hard substrates via byssus	[1]
	- sexually mature after spring in third year (~75 mm)	[4]
	- growth rate positively correlated with water temperature and food availability	[125

References

1. Packer, D.B., et al., *Essential Fish Habitat Source Document: Sea scallop, Placopecten magellanicus, life history and habitat characteristics.* NOAA Tech. Memo. Rep., 1999. NMFS-NE-134: 21 p.
2. Stewart, P.L. and S.H. Arnold, *Environmental requirements of the sea scallop (*Placopecten magellanicus*) in eastern Canada and its response to human impacts.* Can. Tech. Rep. Fish. Aquat. Sci., 1994. **2005**: 1-36.
3. MacKenzie Jr., C.L., A.S. Merrill, and F.M. Serchuk, *Sea scallop resources off northeastern US coast, 1975.* Mar. Fish, Rev., 1978. **40**: 19-23.
4. Posgay, J.A., *Sea scallop* Placopecten magellanicus. Pages 130-133. In *Fish distribution*, M.D. Grosslein and T.Z. Azarovitz, Editors. 1982, N.Y. Sea Grant Institute: Albany, N.Y.

5. Parsons, G.J., M.J. Dadswell, and J.C. Roff, *Influence of biofilm on settlement of sea scallop,* Placopecten magellanicus *(Gmelin, 1791), in Passamaquoddy Bay, New Brunswick, Canada.* J. Shellfish Res., 1993. **11**: 295-297.

6. Parsons, G.J., C.R. Warren-Perry, and M.J. Dadswell, *Movements of juvenile sea scallops* Placopecten magellanicus *(Gmelin, 1791) in Passamaquoddy Bay, New Brunswick.* J. Shellfish Res., 1992. **11**: 295-297.

7. Baird, F.T., *Migration of the deep sea scallop (*Pecten magellanicus*).* Maine Dep. Sea Shore Fish. Circ., 1954. **14**: 1-8.

8. Dadswell, M.J. and G.J. Parsons, *Exploiting life-history characteristics of the sea scallop,* Placopecten magellanicus *(Gmelin, 1791) from different geographical locations in the Canadian Maritimes to enhance suspended culture grow-out.* J. Shellfish Res., 1992. **11**: 299-305.

9. Barber, B.J., et al., *Reduced fecundity in deep-water population of the giant scallop* Placopecten magellanicus *in the Gulf of Maine.* Mar. Ecol. Prog. Ser., 1988. **42**: 207-212.

10. Langton, R.W., W.E. Robinson, and D. Schick, *Fecundity and reproductive effort of sea scallops,* Placopecten magellanicus, *from the Gulf of Maine.* Mar. Ecol. Prog. Ser., 1987. **37**: 19-25.

11. MacDonald, B.A. and R.J. Thompson, *Influence of temperature and food availability on the ecological energetics of the giant scallop* Placopecten magellanicus *III. Physiological ecology, the gametogenic cycle and scope for growth.* Mar. Biol., 1986. **93**: 37-48.

12. Grant, J. and P.J. Cranford, *Carbon and nitrogen scope for growth as a function of diet in the sea scallop* Placopecten magellanicus. J. Mar. Biol. Assoc. U. K., 1991. **71**: 437-450.

13. Thouzeau, G., G. Roberts, and S.J. Smith, *Spatial variability in dsitribution and growth of juvenile and adult sea scallops* Placopecten magellanicus *(Gmelin) on eastern Georges Bank (northwest Atlantic).* Mar. Ecol. Prog. Ser., 1991. **74**: 205-218.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Common Barnacle *Semialanus balanoides*	Source
Abiotic Factors		
Temperature	- below -18 °C for > 18 hr lethal during winter - can tolerate up to 43 °C, heat coma induced at 37 °C - mean monthly sea temperature must be < 7.2 °C for breeding to occur, no fertilization occurs above 10 °C	[1] [1], [2] [3]
Salinity	- can tolerate down to 14 ‰ - can tolerate salinities between 12 and 50 psu, below this cirral activity ceases - survives periodic immersion in freshwater from freshwater runoff or rain - withstand long periods of large changes in salinity by going into "salt sleep" mode (low respiration, no motor activity)	[1] [4] [5] [6]
Oxygen	- can respire anaerobically - mean survival time in wet nitrogen is up to 5 days - can survive low O_2 for a week	[3] [7] [3]
Substrate preference	- upper eulittoral zone of intertidal rocky shores - on boulder, cobble & sometimes gravel, in crevices, or on pilings	[3] [3]
Water current and tides	- needed for larval dispersal - can withstand high water flow rates	[3] [3]
Use of cover	- in upper shore long-term survival of spat reaching > 6 mm under macroalgal cover was enhanced due top protection from desiccation	[8]
Biotic Factors		
Spawning time	- fertilization begins in October - decreasing day length influences fertilization	[9] [9]
Spawning habitat	- needs water, obligate cross-fertilizing hermaphrodite - insemination by more than one male is required for all eggs to be fertilized in a female	[3] [3]
Eggs	- 348 μm long - fertilised embryos are held in two egg sacs, incubated in the mantle cavity over winter - hatching into larvae is triggered by hatching substance released after phytoplankton ingestion - larval phase for about 10 days - nauplii released in March to April (spring algal bloom) - numbers of eggs produced dependent upon size and age of individuals (4200 to 19,000)	[9] [3] [3] [9], [10] [9] [10]
Foods	- suspension feeder, extend their legs out of the top of shell to collect plankton with grasping movements - feeding occurs when water covered mostly during spring & fall, little or no feeding during winter - pronounced ability to withstand & recover from starvation	[3] [3] [1]
Other	- adults secrete a protein (arthropodin) to attract cypris larvae to the eulittoral	[11]

	- growth via moulting is temperature & food dependent	[3]
	- fast growth early life slower later (23-160 µm/day)	[3]
	- 3 to 5 yr life expectancy, but may live up to 8 yrs	[10], [3]
	- desiccation median lethal times: 6 mm animals at 0% humidity is 54 hr (size and location on shore dependent)	[1], [3]
	- adults tolerant to moderate amounts of oil & very tolerant of effluents that are toxic and have low pH	[1]
	- sessile, loss of substratum results in loss of population	[3]
	- sensitive to smothering by sediment	[3]
	- fairly sensitive to chemical pollution	[3]
	- tolerate fairly high level of heavy metals	[3]
	- show high resistance to oil contamination	[3]
	- smothering by algal blooms under eutrophic conditions	[3]

References

1. Perkins, E.J., *The biology of estuaries and coastal waters*. 1974, New York, New York: Academic Press. 678 pp.
2. Southward, A.J., *On the behaviour of barnacles. I. The relation of cirral and other activities to temperature*. J. Mar. Biol. Assoc. U. K., 1955. **34**: 403-432.
3. White, N., Semibalanus balanoides. *An acorn barnacle. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2001, Marine Biological Association of the United Kingdom. [cited 8/11/2004]: Plymouth.
4. Foster, B.A., *Responses and acclimation to salinity in the adults of some balanomorph barnacles*. Phil. Trans. Royal Soc. Lond. Ser. B, 1970. **256**: 377-400.
5. Foster, B.A., *On the determinants of the upper limit of intertidal distribution of barnacles*. J. Anim. Ecol., 1971. **40**: 33-48.
6. Barnes, H., *The effect of lowered salinity on some barnacle nauplii*. J. Anim. Ecol., 1953. **22**: 328-330.
7. Barnes, H., D.M. Finlayson, and J. Piatigorsky, *The effect of desiccation and anaerobic conditions on the behaviour, survival and general metabolism of three common cirripedes*. J. Anim. Ecol., 1963. **32**: 233-252.
8. Jenkins, S.R., et al., *Spatial and temporal variation in settlement and recruitment of the intertidal barnacle* Semibalanus balanoides *(L.) (Crustacea: Cirripedia) over a European scale*. J. Exp. Mar. Biol. Ecol., 2000. **243**: 209-225.
9. Barnes, M., *Egg production in Cirripedia*. Oceangr. Mar. Biol. Ann. Rev., 1989. **27**: 91-166.
10. Arnold, D.C., *Fecundity of* Balanus balanoides *in Passamaquoddy Bay*. J. Fish. Res. Bd. Can., 1977. **34**: 273-275.
11. Gosner, K.L., *A Field Guide to the Atlantic Seashore*. 1978, Boston: Houghton Miffin Company. 309 pp.

Species Life Requirements/Habitats: Musquash Estuary (after [1])		
Species	Green shore crab *Carcinus maenas*	Source
Abiotic Factors		
Temperature	- tolerant of temperatures from 5 to 26 °C - not active at temperatures < 2 °C - activity reduced at < 7 °C - adults will not breed over 18 °C	[2] [3] [3] [4]
Salinity	- lethal below 7 ‰ - tolerates a wide range of salinities from 4 to 40 psu, but prefers 27 to 40 psu - salinity tolerance increases with temperature	[3] [4] [4]
Oxygen	- can survive up to 18 hr in complete anoxia - tolerant of low O_2, consumption drops to 20% of that in normoxic conditions	[4] [4]
Substrate preference	- found at low tide under rocks, buried in sand, or under rockweed - during high tide moves about in the intertidal zone on types of substrates, prefers sheltered shores - abundant in estuaries and salt marshes	[5] [4] [4]
Water current and tides	- assumed important for larval dispersion > 10 km	[4]
Use of cover	- bury in sediments - under rocks, ocean debris & intertidal algae at low tide	[3] [6]
Biotic Factors		
Spawning time	- ripe females in spring	[5]
Spawning habitat	- males copulate with newly moulted females - females carry eggs up to 4 months depending on temperature, eggs hatch in summer	[4] [4]
Eggs	- maximum fecundity recorded of 185,000 eggs - larvae settle out of water after 1 to 1.5 months	[7] [7]
Foods	- feeds on clams, mussels, oysters, polychaetes, snails - omnivorous - some plant matter including algae and cord grass *Spartina* sp. can be consumed - juveniles on rocky shores consume intertidal barnacles	[8] [3] [4] [9]
Other	- increases body size by 20-33% per moult - takes about 10 moults to reach 20 mm carapace width (CW) in first year - life span of 5 to 10 years - mobility enhances survival in when substratum is lost - smothering may not be a big factor for adults but post settlement survival is reduced in such environments - tolerant of turbid estuarine waters - fairly tolerant of desiccation - tolerant of deceased flow - abrasion & physical disturbance likely to be temporary - high mortality when exposed to synthetic compounds - high levels of mercury exposure causes mortality - high intolerance to hydrocarbon pollution	[10] [10] [4] [4] [4] [4] [4] [4] [4] [4] [4] [4]

References

1. Parker, M.A. and R.J. Rutherford, *Musquash Ecosystem Framework Development*. 2003, East Coast Aquatics & Thaumas Environmental: Dartmouth, Nova Scotia. 39 pp.
2. Truchot, J.P., *Temperature and acid-base regulation in the shore crab* Carcinus maenas *(L.)*. Respiration Physiol., 1973. **17**: 11-20.
3. Ropes, J.W., *The feeding habits of the green crab* Cracinus maenas *(L.)*. Fish. Bull., 1968. **67**: 183-203.
4. Neal, K.J. and P.F. Pizzolla, *Carcinus maenas. Common shore crab: Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2004, Marine Biological Association of the United Kingdom [cited 08/06/2004]: Plymouth.
5. Naylor, E., *Seasonal changes in a population of* Carcinus maenas *(L.) in the littoral zone*. J. Anim. Ecol., 1962. **31**: 601-609.
6. Berrill, M. and D. Berrill, *The North Atlantic Coast: A Sierra Club Naturalist's Guide*. 1981, San Francisco: Sierra Clob Books. 464 pp.
7. Crothers, J.H., *The biology of the shore crab* Carcinus maenas *(L.) I. The background-anatomy, growth and life history*. Field Studies, 1967. **2**: 407-434.
8. Elner, R.W., *Crabs of the Atlantic coast of Canada*. In *Underwater World*. 1989, Communications Directorate, Fisheries and Oceans Canada: Ottawa. 8 pp.
9. Rangeley, R.W. and M.L.H. Thomas, *Predatory behaviour of juvenile shore crab* Carcinus maenas *(L.)*. J. Exp. Mar. Biol. Ecol., 1987. **108**: 191-197.
10. Klein Breteler, W.C.M., *Laboratory experiments on the influence of environmental factors on the frequency of moulting and the increase in size at the moulting of juvenile shore crabs,* Carcinus maenas. Neth. J. Sea Res., 1975. **9**: 100-120.

Species Life Requirements/Habitats: Musquash Estuary (after [1])		
Species	*Corophium volutator*	Source
Abiotic Factors		
Temperature	- lowest lethal temperature -3.3 °C for summer generations and -8.4 for winter generations - upper lethal temperature 38.7 °C at 20 ppt - burrows deeper when < 4 °C - reproduction ceases < 7 °C	[2] [2] [3] [4]
Salinity	- euryhaline, tolerance of 2 to 50 psu, prefers 10 to 30 ‰ - minimum 2 ‰ (absent below 2 ‰) - 0 to 30 ‰, may move in and out depending on salinity - 5 to 30 ‰ for maximum growth rates - low salinity tolerance (2 to 10 ‰) - 20 ‰ required to lay eggs - can survive 500 hr at 2 to 50 ‰ - fastest growth at 15 to 20 ‰	[5] [4] [6], [7] [4] [2] [2] [8] [6]
Oxygen	- sensitive to hypoxia, 50% mortality in 4 hrs under hypoxic conditions, or in 2hr if there is a rapid build up of sulphide - drifting macroalgae can create hypoxic conditions when settled on mudflats	[9] [7]
Substrate preference	- prefers sediments of predominantly silt-sized particles less that 44 microns - in laboratory showed preference for sediments with reduced oxygen content - found in salt marsh pools and brackish water ditches	[10] [11] [7]
Water current and tides	- settling behaviour does not differ between still and flowing water - currents assist in dispersal - increases in water flow can sweep away swimming individuals especially juveniles	[12] [12] [7]
Cover	- forms U-shaped burrows in sediments	[10]
Biotic Factors		
Spawning time	- late June and late August through September - early May until early August in Bay of Fundy	[13], [14]
Spawning habitat	- on receding tide males search for females by crawling about on the surface - copulation occurs in burrows after the female moults - sperm released into the water, swept into the marsupium on currents produced by female pleopods - eggs released almost immediately into the marsupium, fertilised and brooded for 14 days	[7] [2] [15] [15]
Eggs	- average brood size of 38 per female - juveniles released on spring tides	[13] [15]
Foods	- mud and organic debris from nearby salt marsh - selective deposit feeder at low tide - suspension feeder at high tide - bacteria and benthic diatoms - particles of 4 to 63 µm in diameter ingested	[4], [11] [16], [10] [7] [17] [7]
Other	- important food source for migrant shorebirds	[18]

	- two generations per year	[2]
	- usually four to ten times more females than males	[19]
	- in outer Bay of Fundy, around and below Saint John, only one annual generation (lower temperatures)	[19]
	- two annual generations in upper Bay of Fundy	[19]
	- bioturbation activities lead to greater availability of contaminated sediments to other filter feeders	[19]
	- any activity (e.g. bloodworm harvesting) that results in disturbance of the mud surface is a potential threat	[19]
	- loss of substratum will result in loss of population	[7]
	- eutrophication followed by blooms of macroalgae results in reduced habitat	[19]
	- high water temperature, reduces resistance to trematode flatworm parasite, causing die offs	[19]
	- migratory shorebirds (e.g. sandpiper) can each consume as many as 50 males on a receding tide during breeding time when males are searching for females	[20]
	- structures constructed on intertidal mud are likely to alter hydrodynamic conditions & increase sediment accretion leading to a drop in numbers	[7]
	- can be smothered by eutrophic growth in mudflat macroalgae such as *Enteromorpha intestinalis*	[7]
	- increase in sediment deposition may cause reduction in numbers	[7]
	- increased wave exposure will disturb sediment and may make it impossible for burrow maintenance	[7]
	- sediment turnover by lugworm disturbs burrows and caused increased swimming activity resulting in exposure to predation	[7]
	- highly intolerant of synthetic chemicals	[7]
	- mercury is very toxic (50% mortality in 12 days at 0.1 mg/l)	[21]
	- highly intolerant of heavy metal pollution	[7]
	- high intolerance for hydrocarbon pollution	[7]

References

1. Parker, M.A. and R.J. Rutherford, *Musquash Ecosystem Framework Development*. 2003, East Coast Aquatics & Thaumas Environmental: Dartmouth, Nova Scotia. 39 pp.
2. Mills, A. and J.D. Fish, *Effect of salinity and temperature on* Corophium volutator *and* C. arenarium *(Crustacea: Amphipoda), with particular reference to distribution*. Mar. Biol., 1980. **58**: 153-161.
3. Perkins, E.J., *The biology of estuaries and coastal waters*. 1974, New York, New York: Academic Press. 678 pp.
4. McKlusky, D.S., *Some effects of salinity on the distribution and abundance of* Corophium volutator *in the Ythan Estuary*. J. Mar. Biol. Assoc. U. K., 1968. **48**: 443-454.
5. McKlusky, D.S., *The oxygen consumption of* Corophium volutator *in relation to salinity*. Comp. Biochem. Physiol., 1969. **29**: 734-753.

6. McKlusky, D.S., *Salinity preferences in* Corophium volutator. J. Mar. Biol. Assoc. U. K., 1970. **50**: 747-752.
7. Neal, K.J. and P. Avant, Corophium volutator. *A mud shrimp. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2004, Marine Biological Association of the United Kingdom. [cited 8/11/2004]: Plymouth.
8. McKlusky, D.S., *Some effects of salinity on the survival, moulting and growth of* Corophium volutator. J. Mar. Biol. Assoc. U. K., 1967. **47**: 607-617.
9. Gamenick, I., et al., *Hypoxia and sulphide as structuring factors in a macrozoobenthic community on the Baltic Sea shore: Colonization studies and tolerance experiments.* Mar. Ecol. Prog. Ser., 1996. **144**: 73-85.
10. Hawkins, C.M., *Population carbon budgets and the importance of the amphipod* Corophium volutator *in the carbon transfer in the Cumberland Basin mudflat, Upper Bay of Fundy, Canada.* Neth. J. Sea Res., 1985. **19**: 165-176.
11. Meadows, P.S. and A. Reid, *The behaviour of* Corophium volutator *(Curstacea: Amphipoda).* J. Zool. Soc. Lond., 1966. **150**: 483-488.
12. Ford, R.B. and D.M. Paterson, *Behaviour of* Corophium volutator *in still versus flowing water.* Estuar. Coast. Shelf Sci., 2001. **52**(3): 357-362.
13. Linkletter, L. and P.W. Hicklin, *Aspects of the life history and reproductive biology of* Corophium volutator *(Pallas), in the Upper Bay of Fundy.* 1980, Canadian Wildlife Service Preliminary Report: Sackville, NB. 39 pp.
14. Gratto, G.W., M.L.H. Thomas, and J S. Bleakney, *Growth and production of the intertidal amphipod* Corophium volutator *in the inner and outer Bay of Fundy.* Proc. N.S. Inst. Sci., 1983. **33**: 47-55.
15. Fish, J.D. and A. Mills, *The reproductive biology of* Corophium volutator *and* C. arenarium *(Crustacea: Amphipoda).* J. Mar. Biol. Assoc. U. K., 1979. **59**: 355-368.
16. Nielson, M. and L. Koefoed, *Selective feeding and epopsammic browsing by the deposit feeding amphipod* Corophium volutator. Mar. Ecol. Prog. Ser., 1982. **10**: 81-88.
17. Cammen, L.M. and J.A. Walker, *The relationship between bacteria and micro-algae in the sedimant of a Bay of Fundy mudflat.* Estuar. Coast. Shelf Sci., 1986. **22**: 91-99.
18. Hicklin, P.W. and P.C. Smith, *The diets of five species of migrant shorebirds in the Bay of Fundy.* Proc. N.S. Inst. Sci., 1979. **29**: 483-488.
19. BOFEP, *KEYSTONE COROPHIUM: Master of the Mudflats*, in *Fundy Issues*. 1999, Bay of Fundy Ecosystem Partnership.
20. Brown, R.J., et al., *Long-term exposure to 4-nonylphenol affects sexual differentiation and growth of the amphipod* Corophium volutator *(Pallas, 1766).* Sci. Total Environ., 1999. **233**: 77-88.
21. Meadows, P.S. and C. Erdem, *The effect of mercury of* Corophium volutator *viability and uptake.* Mar. Environ. Res., 1982. **6**: 227-233.

Species Life Requirements/Habitats: Musquash Estuary (after [1])		
Species	Amphipod *Gammarus oceanicus*	Source
Abiotic Factors		
Temperature	- not found in temperatures < 2 °C	[2]
Salinity	- not found in salinities < 2.5 ‰	[2]
Oxygen	- no data found	
Substrate preference	- sheltered moderately exposed intertidal coasts under rocks and algae	[2], [3]
Water current and tides	- no data found	
Use of cover	- hides under rocks and in algae - significant use of rockweed as cover and food	[1] [1]
Biotic Factors		
Spawning time	- successive broods, December through August - summer	[2], [3]
Spawning habitat	- no data found	
Eggs	- eggs brooded	[3]
Foods	- scavenger	[3]
Other	- possibly the most common of all understory organism in the intertidal	[3]

References

1. Parker, M.A. and R.J. Rutherford, *Musquash Ecosystem Framework Development*. 2003, East Coast Aquatics & Thaumas Environmental: Dartmouth, Nova Scotia. 39 pp.
2. Steele, D.H. and V.J. Steele, *The biology of* Gammarus *(Crustacea, Amphipoda) in the Northwestern Atlantic VII. The duration of embroynic development in five species at various temperatures.* Can. J. Zool., 1972. **51**: 995-999.
3. Berrill, M. and D. Berrill, *The North Atlantic Coast: A Sierra Club Naturalist's Guide*. 1981, San Francisco: Sierra Clob Books. 464 pp.

Species Life Requirements/Habitats: Musquash Estuary		
Species	American lobster *Homarus americanus*	Source
Abiotic Factors		
Temperature	- slow embryo development below 6 °C - duration of hatching varies with temperature, longer at lower temperature - juveniles found in 0 to 25 °C and can tolerate abrupt temperature changes - pre-adults can tolerate 1.8 to 30.5 °C	[1] [2] [1] [3]
Salinity	- embryonic development slower at lower salinities - survival of post-larval stages higher at 35 ‰ at 15 °C and at lower salinities at higher temperatures - survival of juveniles good at >10.2 ‰ - metabolically stressful at <15 ‰, mortality at <10 ‰	[4] [5] [6] [4]
Oxygen	- larval stages complete mortality within 2 hr in hypoxia - postlarval, juveniles and adults tolerant of low O_2	[7] [3]
Substrate preference	- from intertidal zone down to as deep as 700 m	[4]
Water current and tides	- little know on how currents affect survival, growth, development rate, or dispersal of larvae	[1]
Use of cover	- early stages have been found associated with drifting macroalgae and patches floating of seaweed - postlarval lobsters settle into algal-covered rocks, gravel, eelgrass, seaweed substrates and salt-marsh peat - shelters provide refuge from predators and adverse environmental conditions	[8], [9] [4] [10]
Biotic Factors		
Spawning time	- hatching occurs as temperatures approaches 15 °C - mating occurs when the female lobster moults	[2] [2]
Spawning habitat	- mating usually occurs in the den of the male during summer months	[2]
Eggs	- have a 10 to 12 month natural incubation attached to maternal pleopods - eggs lost from pleopods when conditions unfavourable - 36% eggs lost between extrusion and hatching	[4] [1] [11]
Foods	- larvae are carnivorous, feed on crab larvae, copepods, caldocerans, invertebrate eggs, nematodes, diatoms & insect remains - post-larvae feed on plankton (copepods) & benthic organisms - adults are omnivorous, feed on crabs, polychaetes, mussels, periwinkles, sea urchins, sea stars, fishes and seaweeds	[4] [12] [4]
Other	- contaminants readily accumulate in lobster tissue - until suitable bottom conditions found, postlarval stage moulting can be delayed for longer-than-average time - first stage larvae especially sensitive to contaminants - larvae peak in abundance in water column during July and August	[4] [13] [1] [14]

References

1. Aiken, D.E. and S.L. Waddy, *Environmental influence on recruitment of American lobster,* Homarus americanus*: a perspective.* Can. J. Fish. Aquat. Sci., 1986. **43**: 2258-2270.
2. Hughes, J.T. and G.C. Matthiessen, *Observations on the biology of the American lobster,* Homarus americanus. Limnol. Oceanogr., 1962. **7**: 414-421.
3. Cooper, R.A. and J.R. Uzmann, *Ecology of juvenile and adults* Homarus. Pages 97-142. In *The biology and management of lobsters*, J.S. Cobb and B.F. Phillips, Editors. 1980, Academic Press: New York, N.Y.
4. Mercaldo-Allen, R. and C.A. Kuropat, *Review of American lobster (*Homarus americanus*): Habitat requirements and responses to contaminant exposures.* NOAA Tech. Memo. Rep., 1994. NMFS-NE-105: 52 pp.
5. Sastry, A.N. and S.L. Vargo, *Variations in the physiological responses of crustacean larvae to temperature.* In *Physiological responses of marine biota to pollutants*, F.J. Vernberg, et al., Editors. 1977, Academic Press: New York, N.Y.
6. Charmantier, G., M. Charmantier-Daures, and D.E. Aiken, *Neuroendocrine control of hydrominerla regulation in the American lobster* Homarus americanus *H. Milne-Edwards 1837 (Crustacea: Decapoda). 1. Juveniles.* Gen. Comp. Endocrinol., 1984. **54**: 8-19.
7. Poucher, S.L. and D.C. Miller. *Effects of reduced oxygen on American lobster larvae (Abstr.).* In *New England Estuarine Research Society Meeting, 25-27 October 1990.* 1990.
8. Grabe, S.A., J.W. Shipman, and W.S. Bosworth, *New Hampshire lobster larvae studies.* Pages 53-56. In *Distribution and relative abundance of American lobster,* Homarus americanus, *larvae : New England investigations during 1974-79*, M.J. Fogarty, Editor. 1983, National Marine Fisheries Service: Seattle, WA.
9. Harding, G.C., W.P. Vass, and K.F. Drinkwater, *Aspects of larval American lobster (*Homarus americanus*) ecology in St. Georges Bay, Nova Scotia.* Can. J. Fish. Aquat. Sci., 1982. **39**: 1117-1129.
10. Cobb, J.S., *The shelter-related behviour of the lobster,* Homarus americanus. Univ. R.I. Mar. Tech. Rep., 1971. **48**: 32 pp.
11. Perkins, H.C., *Egg loss during incubation from offshore northern lobsters (Decapoda: Homaridae).* U.S. Fish. Bull., 1971. **69**: 451-453.
12. Lavalli, K.L., *Food capture in post-larval American lobsters (Abstr.).* Amer. Zool., 1988. **28**: 154A.
13. Cobb, J.S., *Delay of moult by the larvae of* Homarus americanus. J. Fish. Res. Bd. Can., 1968. **25**: 2251-2253.
14. Lund Jr., W.A. and L.L. Stewart, *Abundance and distribution of larval lbsters,* Homarus americanus, *off the coast of Southern New England.* Proc. Nat. Shellfish Assoc., 1970. **60**: 40-49.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Sea vase *Ciona intestinalis*	Source
Abiotic Factors		
Temperature	- in the Mediterranean, growth is optimal at between 15-20°C & most of the adult population dies below 10 °C - short-term acute changes in temperature, particularly decreases may cause some of the population to die - growth rate is temperature dependent - in Sweden do not begin to reproduce until temperature rises above 8 °C	[1] [1] [1] [1]
Salinity	- inhabits a variety of salinities (down as low as 11 psu) but more typically above 20 psu - in Mediterranean, optimal salinity for adults is 35 psu - in Sweden, reproductive frequency and longevity vary with depth and salinity	[1] [1] [1]
Oxygen	- frequently found in areas with restricted water renewal where oxygen concentrations may drop - no other information found	[1]
Substrate preference	- lower shore down to at least 500 m, common in man-made environments such as harbours and marinas - grows on bedrock and boulders but also artificial surfaces such as metal and concrete - can occur in dense aggregations dominating the substratum	[1] [1] [1]
Water current and tides	- prefers low exposure with some water flow	[1]
Use of cover	- no information found	
Biotic Factors		
Spawning time	- semelparous and annual to iteroparous - annual protracted throughout the year in British waters - in Sweden gamete release peaks in May/June - light intensity may have a role in spawning and settlement but reproduction occurs throughout the yr - in laboratory spawning occurred within 4 min (±2.6) of exposure to light; spawning at dawn	[1] [1] [1] [1] [2]
Spawning habitat	- permanently hermaphroditic	[1]
Eggs	- negatively buoyant, 160 microns in diameter, yolky and red or green in colour - eggs released individually or in strings - viable up to 30 hrs after release, external fertilization - oviparous with lecithotrophic larval development which is temperature dependent - larvae may be dispersed or retained in mucus until larval settling time in a few hrs to 10 days	[1] [1] [1] [1] [1]
Foods	- active suspension feeder on seston	[1]
Other	- large, solitary, grows up to 15 cm, lifespan 1 to 2 yr - growth rate dependent on temperature and body size - sessile, loss of substratum means loss of population - adults can be 15 cm long and on vertical surfaces smothering with 5 cm of sediment will probably only	[1] [1] [1] [1]

	affect a proportion of the population	
	- high levels of siltation may potentially have some detrimental effects in clogging up feeding filtration mechanisms, but this species is known to thrive in such areas & may be a good indicator of stressed areas experiencing sedimentation excess	[3]
	- exposure to desiccating influences for one hour will probably kill a proportion of the population	[1]
	- high water flow rates may be detrimental to feeding ability and posture, but a reasonable water flow rate is needed to ensures sufficient food availability	[1]
	- probably has little or no requirement for light and may be found down to 500 m depth	[1]
	- increased wave action can result in physical damage and cause abrasion by sediment	[1]
	- physical disturbance by a passing scallop dredge is likely to cause physical damage and death	[1]
	- capable of accumulating trace elements such as heavy metals but no information on the effects	[1]
	- capable of accumulating iron, hence, can be used as an indicator of iron	[4]

References

1. Jackson, A., Ciona intestinalis. *A sea squirt. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. 2000, Marine Biological Association of the United Kingdom. [cited 8/11/2004]: Plymouth.
2. Whittingham, D.G., *Light-induction of shedding of gametes in* Ciona intestinalis *and* Morgula manhattensis. Biol. Bull. Woods Hole, 1967. **132**: 292-298.
3. Naranjo, S.A., J.L. Carballo, and J.C. Garcia-Gomez, *Effects of environmental stress on ascidian populations in Algeciras Bay (southern Spain). Possible marine bioindicators?* Mar. Ecol. Prog. Ser., 1996. **144**: 119-131.
4. Papadopoulou, C. and G.D. Kanias, *Tunicate species as marine pollution indicators.* Mar. Poll. Bull., 1977. **8**: 229-231.

Species Life Requirements/Habitats: Musquash Estuary (after [1])		
Species	Mummichog *Fundulus heteroclitus*	Source
Abiotic Factors		
Temperature	- upper lethal at 14 ppt is 34 °C - tolerant of wide range of temperature	[2] [3]
Salinity	- common over a wide range of salinities, upper limits at 10 °C of 106-120.3 ppt	[2]
Oxygen	- very tolerant of low oxygen concentration - can survive in stagnant waters for long periods - breathes air when out of water - O_2 concentration and hydration controls egg development	[2], [4] [4] [5] [6]
Substrate preference	- benthopelagic, marshy areas and brackish waters with submergent or emergent vegetation - prefer areas with *Spartina* over bare mud	[2], [4] [7]
Water current and tides	- tidal currents influence distribution	[4]
Use of cover	- sheltered shores in *Spartina* (eelgrass) beds in water	[4]
Biotic Factors		
Spawning time	- spawning occurs in shallow waters from April to August depending on water temperature - cyclical and correlated with high tides - can spawn up to 8 times in one season	[2] [8] [8]
Spawning habitat	- eggs may be deposited on aquatic plants, on masses of algae, in sand and mud, in mussel shells, in few inches of water in a shady spot	[2], [4]
Eggs	- about 2.1 mm in diameter, spherical, pale yellow and adhesive, deposited intertidally - 100 to 300 eggs per day for 3 to 5 days is not unusual - deposited in clutches of 10 to 300, hidden in leaves or empty mussel shells, or in substrate - eggs normally incubate in air and are not submerged until the next spring tide - hatching takes 7-8 days at 22-34 °C	[2] [8] [8] [8] [9]
Foods	- omnivorous, variety of small crustaceans, polychaetes, insect larvae and vegetable matter - cannot subsist on a diet of plant material or detritus, does not assimilate plant material	[2] [10]
Other	- resident intertidal species with homing behaviour - widely used as an experimental animal, especially for studies of endocrinology - size at maturity: males 32 mm, females 38 mm - burrow down into mud in pannes during winter - total production of mummichogs in salt marshes among the highest recorded for natural populations - stress- and pollution-tolerant	[11] [8] [7] [8] [12] [13]

References

1. Parker, M.A. and R.J. Rutherford, *Musquash Ecosystem Framework Development*. 2003, East Coast Aquatics & Thaumas Environmental: Dartmouth, Nova Scotia. 39 pp.
2. Scott, W.B. and M.G. Scott, *Atlantic fishes of Canada*. Can. Bull. Fish. Aquat. Sci. 219. 1988, Ottawa: University of Toronto Press; Minister of Fisheries and Oceans; Canadian Government Publishing Centre. xxx + 731 pp.
3. Scott, W.B. and E.J. Crossman, *Freshwater fishes of Canada*. Fish. Res. Board Can. Bull., 1973. **184**.
4. Bigelow, H.B. and W.C. Schroeder, *Fishes of the Gulf of Maine*. Revision 1.1 2002, Online Edition ed. Fish. Bull. 74; Fish. Bull. Fish and Wildlife Serv. 53; Contribution (Woods Hole Oceanographic Institution) No. 592. 2002, Washington: United States Government Printing Office. viii + 577 pp.
5. Martin, K.L.M. and C.R. Bridges, *Respiration in water and air*. Pages 54-78. In *Intertidal fishes: Life in two worlds*, M.H. Horn, K.L.M. Martin, and M.A. Chotkowski, Editors. 1999, Academic Press.
6. DiMichele, L. and M.H. Taylor, *The mechanism of hatching in* Fundulus heteroclitus*: development and physiology*. J. Exp. Zool., 1981. **217**: 73-80.
7. Hildebrand, S.F. and W.C. Schroeder, *Fishes of Chesapeake Bay*. (Reprinted 1972) ed. 1928, Washington, D.C: Smithsonian Institution Press. 366 pp.
8. Abraham, B.J., *Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic)--mummichog and striped killifish*. U.S. Fish Wildl. Serv. Biol. Rep., 1985. 82(11.40) U.S. Army Corps of Engineers, TR EL-82-4. 23 pp.
9. Taylor, M.H., L. DiMichele, and G.J. Leach, *Egg stranding in the life cycle of the mummichog* Fundulus heteroclitus. Copeia, 1977. **1977**: 397-399.
10. Katz, L.M., *Laboratory studies on diet, growth, and energy requirements of* Fundulus heteroclitus *(Linnaeus)*. 1975, University of Delaware: Newark. 81 pp.
11. Gibson, R.N., *Movement and homing in intertidal fishes*. Pages 97-125. In *Intertidal fishes: Life in two worlds*, M.H. Horn, K.L.M. Martin, and M.A. Chotkowski, Editors. 1999, Academic Press.
12. Valiela, I., et al., *Growth, production and enerqy transformations in the saltmarsh kiilifish,* Fundulus heteroclitus. Mar. Biol., 1977. **40**: 135-144.
13. Huver, C.W., *A bibliography of the genus Fundulus*. 1973, Boston: G.K. Hall and Co. 138 pp.

Species Life Requirements/Habitats: Musquash Estuary (after [1])		
Species	Three-spined stickleback *Gasterosteus aculeatus*	Source
Abiotic Factors		
Temperature	- 1.3 to 19 °C	[2]
	- 0 to 16 °C in Bellevue, Newfoundland	[3]
	- 0 to 25 °C in the St. Lawrence estuary	[4]
	- in laboratory preferred 9 to 12 °C	[5]
Salinity	- lives whole life under estuarine conditions but at home under full sea water salinity and freshwater	[6]
	- juveniles in caught in 18 to 32 ppt	[2]
	- 7 to 14 preferred in experimental setting	[7]
Oxygen	- no information found	
Substrate preference	- tolerant of marine, brackish and freshwaters mainly occupying shallow coastal areas	[8]
	- tidal marsh pools and shallow protected coves in the Bay of Fundy	[2]
	- benthopelagic over a variety of substrates: sand, gravel and mud	[2]
	- associated with eelgrass and filamentous algae	[6]
Water current and tides	- adults inhabit offshore ~135 km (where species is rare)	[6]
Use of cover	- hides in rockweed and eelgrass	[6]
	- forms schools	[6]
Biotic Factors		
Spawning time	- migrate to shallow waters to spawn	[6]
	- size at maturation 40 mm (54 mm in N.J.)	[6]
	- takes place in freshwater during warm summer months of May & June in N.B.	[8], [6]
	- many males die off after spawning	[9]
Spawning habitat	-builds nests of twigs in shallow sandy areas	[8]
Eggs	- 1.5 to 1.7 mm in diameter, adhesive and yellow, semi-opaque, tended by male in nest	[8]
	- demersal, 1.3 to 1.5 mm in St. Lawrence estuary	[10]
	- incubation is 6 to 10 days	[6]
Foods	- voracious feeder on small invertebrates, copepods, euphausiids, gammarids, oligochaetes, hemipterans, chironomids, stickleback eggs, isopods in the sea, mosquito larvae and puape, planktonic eggs	[8], [9], [10]
Other	- 6 to 10 days embryonic development	[11]
	- max size 100 mm, juvenile 21-60 mm	[8], [2]
	- rapid growth rate ~10 mm/yr	[12]
	- juveniles more active at night	[2]

References

1. Parker, M.A. and R.J. Rutherford, *Musquash Ecosystem Framework Development*. 2003, East Coast Aquatics & Thaumas Environmental: Dartmouth, Nova Scotia. 39 pp.
2. Casselman, J. and D.A. Methven, *A comparison of the seasonal occurrences of nearshore fishes in the lower Bay of Fundy: Passamaquoddy Bay, Musquash area and approaches to Saint John Harbour*. 2004, University of New Brunswick: Saint John, NB. Unpublused report done for DFO.
3. Methven, D.A., R.L. Haedrich, and G.A. Rose, *The fish assemblage of a Newfoundland estuary: diel, monthly and annual variation.* Estuar. Coast. Shelf Sci., 2001. **52**: 669-687.
4. Cowen, R.K., et al., *Distribution, age and lateral plate variation of larvel stickleback (*Gasterosteus*) off the Atlanticcoast of New Jersey, New York and southern New England.* Can. J. Fish. Aquat. Sci., 1991. **48**: 1679-1684.
5. Lachance, S. and P. Magan, *Temperature preferences of three sympatric sticklebacks (Gasterosteidae).* Can. J. Zool., 1987. **65**: 1573-1576.
6. Bigelow, H.B. and W.C. Schroeder, *Fishes of the Gulf of Maine*. Revision 1.1 2002, Online Edition ed. Fish. Bull. 74; Fish. Bull. Fish and Wildlife Serv. 53; Contribution (Woods Hole Oceanographic Institution) No. 592. 2002, Washington: United States Government Printing Office. 577 pp.
7. Audet, C., G.J. FitzGerald, and H. Guderley, *Salinity preferences of four sympatric species of sticklebacks (Pisces: Gasterosteidae) during their reproductive season.* Copeia, 1985. **1985(1)**: 209-213.
8. Scott, W.B. and M.G. Scott, *Atlantic fishes of Canada*. Can. Bull. Fish. Aquat. Sci. 219. 1988, Ottawa: University of Toronto Press; Minister of Fisheries and Oceans; Canadian Government Publishing Centre. xxx + 731 pp.
9. Delbeek, J.C. and D.D. Williams, *Food resource partitioning between sympatric pooulations of brackish water sticklebacks.* J. Anim. Ecol., 1987. **56**: 949-967.
10. Coad, D.M. and G. Power, *Observations on the ecology and phenotypic variation of the threespine stickleback,* Gasterosteus aculeatus, *and the blackspotted stickleback,* G. wheatlandi *(Osteichthyes: Gasterosteidae) in Armory Cove, Quebec.* Can. Field Natur., 1973. **87**: 113-122.
11. Able, K.W. and M.P. Fahay, *The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight*. 1998, New Brunswick, New Jersey: Rutgers University Press. 342 pp.
12. Jones, P.W. and H.B.N. Hynes, *The age and growth of* Gasterosteus aculeatus, Pygosteus pungitius *and* Spinachia vulgaris, *as shown by their otoliths.* J. Anim. Ecol., 1950. **19**: 59-73.

Species Life Requirements/Habitats: Musquash Estuary (after [1])		
Species	Blackspotted stickleback *Gasterosteus wheatlandi*	Source
Abiotic Factors		
Temperature	- 3 to 17.5 °C in lower Bay of Fundy - 0 to 16 in Bellevue, Newfoundland - in laboratory preferred 11 to 14 °C	[2] [3] [4]
Salinity	- almost strictly marine - may frequent freshwaters - 16 to 32 ppt in lower Bay of Fundy - preferred 21 ppt in laboratory	[5] [5] [2] [6]
Oxygen	- no data found	
Substrate preference	- in shallow waters of 2.7 m or less; semipelagic - less than 1.2 m depth over a variety of substrates: sand, gravel mud - tide pools, brackish waters and along shorelines	[5] [2] [7], [8]
Water current and tides	- no data found	
Use of cover	- swims near floating seaweed	[5]
Biotic Factors		
Spawning time	- mid-summer (late June and July in brackish waters in Long Island, NY) - males 33 mm, females 37 mm at maturity in NB	[5], [9] [10]
Spawning habitat	- build nests in shallow freshwaters	[5], [11]
Eggs	- vary in size from 1.2 to 1.5 cam in diameter	[5]
Foods	- small invertebrates, small fishes and eggs - oligochaetes, copepods, small crustaceans, eggs - amphipods, ostracods, rotifers, Branchiura and Hemiptera in a Quebec tidal marsh - mainly copepods in the Bay of Fundy	[2] [12],[13] [14] [15]
Other	- 76 mm maximum size on Atlantic coast - 64 mm maximum size in Newfoundland - growth rate ~2 mm/month	[16] [16] [15]

References

1. Parker, M.A. and R.J. Rutherford, *Musquash Ecosystem Framework Development*. 2003, East Coast Aquatics & Thaumas Environmental: Dartmouth, Nova Scotia. 39 pp.
2. Casselman, J. and D.A. Methven, *A comparison of the seasonal occurrences of nearshore fishes in the lower Bay of Fundy: Passamaquoddy Bay, Musquash area and approaches to Saint John Harbour*. 2004, University of New Brunswick: Saint John, NB. Unpublused report done for DFO.
3. Methven, D.A., R.L. Haedrich, and G.A. Rose, *The fish assemblage of a Newfoundland estuary: diel, monthly and annual variation*. Estuar. Coast. Shelf Sci., 2001. **52**: 669-687.
4. Lachance, S. and P. Magan, *Temperature preferences of three sympatric sticklebacks (Gasterosteidae)*. Can. J. Zool., 1987. **65**: 1573-1576.

5. Scott, W.B. and M.G. Scott, *Atlantic fishes of Canada*. Can. Bull. Fish. Aquat. Sci. 219. 1988, Ottawa: University of Toronto Press; Minister of Fisheries and Oceans; Canadian Government Publishing Centre. xxx + 731 pp.
6. Audet, C., G.J. FitzGerald, and H. Guderley, *Salinity preferences of four sympatric species of sticklebacks (Pisces: Gasterosteidae) during their reproductive season*. Copeia, 1985. **1985(1)**: 209-213.
7. McAllister, D.E., *Le* Gasterosteus wheatlandi, *nouvelle espece de poisson pour la province du Quebec*. Natur. Can., 1960. **87**: 117-118.
8. Nelson, J.S., *Salinity tolerance of brook sticklebacks,* Culaea inconstans, *freshwater ninespine sticklebacks,* Pungitius pungitius, *and fourspine sticklebacks,* Apeltes quadracus. Can. J. Zool., 1968. **46**: 663-667.
9. Perlmutter, A., *Observations on fishes of the genus* Gasterosteus *in the waters of Long Island, New York*. Copeia, 1963. **1963(1)**: 168-173.
10. Rowland, W.J., *Interspecific aggression and dominance in* Gasterosteus. Environ. Biol. Fishes, 1983. **8**: 269-277.
11. Bigelow, H.B. and W.C. Schroeder, *Fishes of the Gulf of Maine*. Revision 1.1 2002, Online Edition ed. Fish. Bull. 74; Fish. Bull. Fish and Wildlife Serv. 53; Contribution (Woods Hole Oceanographic Institution) No. 592. 2002, Washington: United States Government Printing Office. viii + 577 pp.
12. Coad, D.M. and G. Power, *Observations on the ecology and phenotypic variation of the threespine stickleback,* Gasterosteus aculeatus, *and the blackspotted stickleback,* G. wheatlandi *(Osteichthyes: Gasterosteidae) in Armory Cove, Quebec*. Can. Field Natur., 1973. **87**: 113-122.
13. Delbeek, J.C. and D.D. Williams, *Food resource partitioning between sympatric populations of brackish water sticklebacks*. J. Anim. Ecol., 1987. **56**: 949-967.
14. Poulin, R. and G.J. FitzGerald, *The potential of parasitism in the structuring of salt marsh stickleback community*. Can. J. Zool., 1987. **65**: 2793-2798.
15. Williams, D.D. and J.C. Delbeek, *Biology of the threespine stickleback,* Gasterosteus aculeatus, *and the blackspotted stickleback,* G. wheatlandi, *during their marine pelagic phase in the Bay of Fundy, Canada*. Environ. Biol. Fishes, 1989. **24**: 33-41.
16. Scott, W.B. and E.J. Crossman, *Freshwater fishes of Canada*. Fish. Res. Board Can. Bull., 1973. **184**.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Atlantic tomcod *Microgadus tomcod*	Source
Abiotic Factors		
Temperature	- 0 to 18 °C - below 0 to 26 °C	[1] [2]
Salinity	- 15 to 33 ppt - 0 to 31.4 ppt	[1] [3]
Oxygen	- no data found	
Substrate preference	- demersal; anadromous; freshwater; brackish; marine - somewhat demersal over a variety of substrates: mud, sand, gravel - juvenile is year round resident of nearshore marine and brackish waters	[4] [1] [5]
Water current and tides	- no data found	
Use of cover	- no data found	
Biotic Factors		
Spawning time	- November to February in Muddy Creek, Harwich, Massachusetts - December to January in Passamaquody Bay	[6] [7]
Spawning habitat	- estuaries and freshwater streams	[4]
Eggs	- demersal, 1.7 mm, weakly adhesive - 1.5 mm diameter - females 170 to 340 mm long produce ~ 6,000 to 30,000 eggs - tolerate a wide range of salinity, deposited near upriver extent of saltwater intrusion - incubation 24 to 60 days, depending on temperature	[8] [9] [10] [4] [5] [11]
Foods	- small crustaceans (especially shrimps & amphipods), worms, small molluscs, squids and fish fry - polychaetes are primary food in Montsweag Bay, Maine	[4] [12]
Other	- no inshore-offshore migrations - short seasonal migrations into streams and rivers in October and November - year round resident in estuaries in Hudson River - size at maturity: 17 cm in Hull, Massachusetts - growth rate ~5 cm/yr - more active at night	[4] [13] [9] [10] [14] [1]

References

1. Casselman, J. and D.A. Methven, *A comparison of the seasonal occurrences of nearshore fishes in the lower Bay of Fundy: Passamaquoddy Bay, Musquash area and approaches to Saint John Harbour*. 2004, University of New Brunswick: Saint John, NB. Unpublused report done for DFO.
2. Gordon, M.S., B.H. Andrews, and P.H. Scholander, *Freezing resistance in some northern fishes*. Biol. Bull. Woods Hole, 1962. **122**: 56-62.

3. Fishke, J.D., C.E. Watson, and P.G. Coates, *A study of the marine resources of Pleasant Bay, Massachusetts.* Mass. Div. Mar. Fish. Monogr. Ser., 1967. **7**: 52 pp.
4. Cohen, D.M., et al., *FAO species catalogue. Vol. 10, Gadiform fishes of the world (Order Gadiformes): an annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date.* FAO Fisheries Synopsis; 125 (10). 1990, Rome: FAO.
5. Able, K.W. and M.P. Fahay, *The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight.* 1998, New Brunswick, New Jersey: Rutgers University Press. 342 pp.
6. Booth, R.A., *A description of the larval stages of the tomcod,* Microgadus tomcod, *with comments on its spawning ecology*, in *Biology*. 1967, University of Connecticut: Storrs.
7. Peterson, R.H., P.H. Johansen, and J.L. Metcalfe, *Observation on the early life stages of Atlantic tomcod,* Microgadus tomcod. U.S. Fish. Bull., 1980. **78**: 147-158.
8. Scott, W.B. and M.G. Scott, *Atlantic fishes of Canada*. Can. Bull. Fish. Aquat. Sci. 219. 1988, Ottawa: University of Toronto Press; Minister of Fisheries and Oceans; Canadian Government Publishing Centre. xxx + 731 pp.
9. Bigelow, H.B. and W.C. Schroeder, *Fishes of the Gulf of Maine*. Revision 1.1 2002, Online Edition ed. Fish. Bull. 74; Fish. Bull. Fish and Wildlife Serv. 53; Contribution (Woods Hole Oceanographic Institution) No. 592. 2002, Washington: United States Government Printing Office. viii + 577 pp.
10. Schaner, E. and K. Sherman, *Observations on the fecundity of the tomcod,* Microgadus tomcod. Copeia, 1959. **1959**: 343-344.
11. Scott, W.B. and E.J. Crossman, *Freshwater fishes of Canada.* Fish. Res. Board Can. Bull., 1973. **184**.
12. Alexander, L.C., *Feeding chronology and food habits of the tomcod* Microgadus tomcod *and winter flounder* Pseudopleuronectes americanus *in Montsweag Bay (Sheepscot River), Maine*, Thesis in *Biology*. 1971, University of Maine: Orono. 36 pp.
13. Pearcy, W.G. and S.W. Richards, *Distribution and ecology of fishes of the Mystic River estuary, Connecticut.* Ecology, 1962. **43**: 248-259.
14. Grabe, S.A., *Food of age 1 and 2 Atlantic tomcod* Microgadus tomcod, *from Haverstraw Bay, Hudson River.* U.S. Fish. Bull., 1980. **76**: 89-94.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Pollock *Pollachius virens*	Source
Abiotic Factors		
Temperature	- 11.8 to 15.2 °C - 8 to 14 °C - juveniles in 0 to 16 °C	[1] [2] [3]
Salinity	- 18 to 28 ppt	[1]
Oxygen	- no data found	
Substrate preference	- active, gregarious, pelagic - somewhat demersal, on Scotian Shelf prefers depth range of 110 to 181 m - juveniles in <1.2 to <1.5 m over a variety of substrates: sand, mud, gravel, rocky - small juveniles migrate to inshore rocky intertidal and subtial zones	[4] [1], [5] [1], [6] [7]
Water current and tides	- would be necessary to bring larvae into the area	
Use of cover	- juveniles show preference for algal habitat along coast	[6]
Biotic Factors		
Spawning time	- November to February in the Gulf of Maine - September to April on the Scotian Shelf	[8] [9]
Spawning habitat	- no evidence of spawning in the Bay of Fundy, larvae likely from spawning grounds in southern Gulf of Maine - on hard, stony or rocky bottom	[10],[11] [3]
Eggs	- average females lay about 220,000 eggs - buoyant, pelagic, transparent, 1 to 1.2 mm in diameter	[4] [5]
Foods	- pelagic crustaceans, small fishes, ctenophores & cephalopods - euphausiids most preyed upon offshore Bay of Fundy - larger individuals prey predominantly upon fishes	[4] [12] [4]
Other	- first 2-3 years remain in shallow coastal waters - migrates inshore during winter, offshore during spring and summer in the Gulf of Maine - size at maturation: males 50 cm, females 48 cm - growth rate ~6 cm/yr in Bay of Fundy - more active at night	[4] [13] [5] [2] [6]

References

1. Casselman, J. and D.A. Methven, *A comparison of the seasonal occurrences of nearshore fishes in the lower Bay of Fundy: Passamaquoddy Bay, Musquash area and approaches to Saint John Harbour*. 2004, University of New Brunswick: Saint John, NB. Unpublused report done for DFO.
2. Steele, D.H., *Pollock (Pollachius virens) in the Bay of Fundy*. J. Fish. Res. Bd. Can., 1963. **20**: 1267-1314.
3. Hardy, J.D., *Development of fishes of the Mid-Atlantic Bight: an atlas of egg, larval and juvenile stages*. Vol. Vol. 2 Anguillidae through Syngnathidae. 1978: U.S. Fish Wildl. Serv. Biol. Prog. FWS/OBS-78/12. 458 pp.

4. Cohen, D.M., et al., *FAO species catalogue. Vol. 10, Gadiform fishes of the world (Order Gadiformes) : an annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date*. FAO Fisheries Synopsis; 125 (10). 1990, Rome: FAO.
5. Able, K.W. and M.P. Fahay, *The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight*. 1998, New Brunswick, New Jersey: Rutgers University Press. 342 pp.
6. Rangeley, R.W. and D.L. Kramer, *Use of rocky intertidal habitats by juvenile pollock* Pollachius virens. Mar. Ecol. Prog. Ser., 1995. **126**: 9-17.
7. Cargnelli, L.M., et al., *Essential Fish Habitat Source Document: Pollock,* Pollachius virens, *life history and habitat characteristics*. NOAA Tech. Memo. Rep., 1999. NMFS-NE-131: 30 pp.
8. Colton, J.B., et al., *Principal spawning areas and times of marine fishes, Cape Sable to Cape Hatteras*. U.S. Fish. Bull., 1979. **19**: 210-223.
9. Markle, D.F. and L.A. Frost, *Comparative morphology, seasonality, and a key to planktonic fish eggs from the Nova Scotian Shelf*. Can. J. Zool., 1985. **63**: 246-257.
10. Scott, J.S., *Occurrence of pollock,* Pollachius virens, *and sand lance,* Ammodytes *sp., larvae in the Bay of Fundy*. J. Northw. Atl. Fish. Sci., 1980. **1**: 45-48.
11. Bigelow, H.B. and W.C. Schroeder, *Fishes of the Gulf of Maine*. Revision 1.1 2002, Online Edition ed. Fish. Bull. 74; Fish. Bull. Fish and Wildlife Serv. 53; Contribution (Woods Hole Oceanographic Institution) No. 592. 2002, Washington: United States Government Printing Office. viii + 577 pp.
12. Scott, W.B. and M.G. Scott, *Atlantic fishes of Canada*. Can. Bull. Fish. Aquat. Sci. 219. 1988, Ottawa: University of Toronto Press; Minister of Fisheries and Oceans; Canadian Government Publishing Centre. xxx + 731 pp.
13. Mayo, R.K., J.M. McGlade, and S.H. Clark, *Patterns of exploitation and biological status of pollock (*Pollachius virens *L.) in the Scotian Shelf, Georges Bank, and Gulf of Maine area*. J. Northw. Atl. Fish. Sci., 1989. **9**: 13-36.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Winter Flounder *Pseudopleuronectes americanus*	Source
Abiotic Factors		
Temperature	- 2 to18 °C in lower Bay of Fundy	[1]
	- 0 to 19 °C in the Gulf of Maine	[2]
	- juveniles not tolerant of changes in temperature >28 °C	[3]
	- inshore juveniles upper incipient lethal at 27 °C	[4]
	- larger fish have lower temperature tolerance	[5]
Salinity	- 10 to 32 ‰	[1],[5]
	- juveniles 7 to 10 mm tolerate 1 to 5 ‰	[5]
Oxygen	- mortality of juveniles occur in 1.1 to 1.5 mg/l dissolved O_2	[6]
	- reduced growth in low dissolved O_2 (2.2 mg/l)	[7]
Substrate preference	- soft muddy to moderately hard bottoms	[8]
	- inshore shallow waters of the Bay of Fundy	[9]
	- very little migration: offshore in the summer, inshore in the winter	[2]
	- juveniles resident in shallow waters	[2]
Water current and tides	- no data found	
Use of cover	- buries in mud and sand; juveniles in can be associated with eelgrass or macroalgae	[10]
Biotic Factors		
Spawning time	- April in Passamaquoddy Bay	[11]
	- January to March in New Jersey	[12]
	- February to March in Massachusetts	[2]
	- February to April in Connecticut	[13]
Spawning habitat	- juveniles found in nearshore nursery habitats	[1]
	- in depths of 0 to 9 m in Passamaquoddy Bay	[4]
Eggs	- demersal, adhesive, on sand, muddy sand, mud and gravel; 0.7-0.9 mm in diameter	[2]
	- hatching takes 11 to 62 days depending on temperature	[7]
	- larvae initially planktonic and eventually benthic-oriented	[5]
Foods	- amphipods, isopods, marine worms, snails, and soft-shelled clams in the Bay of Fundy	[14]
	- can modify diet based on prey availability	[5]
Other	- size at maturation: males 20 cm, females 25 cm	[8]
	- growth rate of ~3 to 4 cm, slower in Passamaquoddy Bay	[1],[15]
	- suspended sediments can interfere with sight and hence feeding	[5]
	- depositional areas may be important for settling of larvae, high numbers are found here	[5]
	- young-of-year lobster prefer undisturbed habitats and spend most of the first year in estuaries	[5],[7]

References

1. Casselman, J. and D.A. Methven, *A comparison of the seasonal occurrences of nearshore fishes in the lower Bay of Fundy: Passamaquoddy Bay, Musquash area and approaches to Saint John Harbour*. 2004, University of New Brunswick: Saint John, NB. Unpublused report done for DFO.
2. Bigelow, H.B. and W.C. Schroeder, *Fishes of the Gulf of Maine*. Revision 1.1 2002, Online Edition ed. Fish. Bull. 74; Fish. Bull. Fish and Wildlife Serv. 53; Contribution (Woods Hole Oceanographic Institution) No. 592. 2002, Washington: United States Government Printing Office. viii + 577 pp.
3. Itkowitz, N. and J.R. Schubel, *Tolerance of five-day-old winter flounder,* Pseudopleuronectes americanus*, larvae to thermal shock.* U.S. Fish. Bull., 1983. **81**: 913-916.
4. McCracken, F.D., *Seasonal movements of the winter flounder,* Pseudopleuronectes americanus*, (Walbaum) on the Atlantic coast.* J. Fish. Res. Bd. Can., 1963. **20**: 551-586.
5. Pereira, J.J., et al., *Winter flounder,* Pseudopleuronectes americanus*, life history and habitat characteristics.* NOAA Tech. Memo. Rep., 1999. NMFS-NE-138: 39 pp.
6. Ziskowski, J.J., et al. *Winter flounder: living in a hypoxic world.* In *Northeast Fisheries Center Research Meetings*. 1991. Woods Hole, MA.
7. Able, K.W. and M.P. Fahay, *The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight*. 1998, New Brunswick, New Jersey: Rutgers University Press. 342 pp.
8. Scott, W.B. and M.G. Scott, *Atlantic fishes of Canada*. Can. Bull. Fish. Aquat. Sci. 219. 1988, Ottawa: University of Toronto Press; Minister of Fisheries and Oceans; Canadian Government Publishing Centre. xxx + 731 pp.
9. Scott, J.S., *Summer distribution of groundfish on the Scotian Shelf, 1970-74.* Dep. Environ. Mar. Serv. Dev. Dir. Tech. Rep., 1976. **635**: 51 pp.
10. Matilla, J., et al., *Spatial and diurnal distribution of invertebrates and fish fauna of a* Zostera marina *bed and nearby unvegetated sedimants in Damariscotta River Maine (USA).* J. Sea Res., 1999. **41**: 321-332.
11. Tyler, A.V., *Periodic and resident components in communities of Atlantic fishes.* J. Fish. Res. Bd. Can., 1971. **28**: 935-946.
12. Scarlett, P.G. and R.L. Allen, *Temporal and spatial distribution of winter flounder (*Pseudopleuronectes americanus*) spawning in Manasquan River, New Jersey.* Bull. N.J. Acad. Sci., 1992. **37**: 13-17.
13. Pearcy, W.G., *Ecology of an estuarine population of winter flounder (*Pseudopleuronectes americanus*). II. Distribution and dynamics of larvae.* Bull. Bingham Oceanogr. Collect. Yale Univ., 1962. **18**: 16-37.
14. Medcof, J.C. and J.S. MacPhail, *The winter flounder - a clam enemy.* Fish. Res. Board Can. Prog. Rep. (Atl.), 1952. **52**: 3-7.
15. McCracken, F.D., *Seasonal movements of the winter flounder,* Pseudopleuronectes americanus *on the Atlantic coast.* Fish. Res. Board Can. Manuscr. Rep., 1954. **582**: 167 pp.

Species Life Requirements/Habitats: Musquash Estuary		
Species	White hake *Urophycis tenuis*	Source
Abiotic Factors		
Temperature	- 11.8 to 15.2 °C - 6 to 16 °C in Bellevue, Newfoundland	[1] [2]
Salinity	- 21 to 31 ppt	[1]
Oxygen	- no data found	
Substrate preference	- demersal on soft, muddy bottoms, continental shelf and upper slope, mostly found at 180 m depth - juveniles in nearshore habitats & estuaries < 1.2 m over a variety of substrates: sand, mud, gravel - juveniles are pelagic for ~2 months	[3] [1],[4] [5]
Water current and tides	- no data found	
Use of cover	- juveniles show some association with drifting algae and eelgrass beds	[6],[7]
Biotic Factors		
Spawning time	- spawns from July to September - late June in southern Gulf of St. Lawrence	[3] [8]
Spawning habitat	- shallow waters	[3]
Eggs	- from 1 to 15 million eggs per female (mostly 2 to 6 million) - buoyant, pelagic, 0.70 to 0.79 mm in diameter	[3] [6]
Foods	- small crustaceans, squids and small fish - adults prey primarily on clupeids, hakes (white, lomgfin, silver, and redfish), Atlantic mackerel and crustaceans - demersal juveniles feed on polychaetes, shrimp & other crustaceans	[3] [9] [10]
Other	- mature fish migrate inshore in the northern Gulf of Maine in summer, disperse in autumn - move into deepest areas in winter - size at maturity: males 33 cm, females 35 cm TL on Georges Bank - growth rate ~5 cm/yr - more active at night - pelagic juveniles become demersal at 50-60 mm TL	[3] [3] [11] [12] [1] [8]

References

1. Casselman, J. and D.A. Methven, *A comparison of the seasonal occurrences of nearshore fishes in the lower Bay of Fundy: Passamaquoddy Bay, Musquash area and approaches to Saint John Harbour*. 2004, University of New Brunswick: Saint John, NB. Unpublished report done for DFO.
2. Methven, D.A., R.L. Haedrich, and G.A. Rose, *The fish assemblage of a Newfoundland estuary: diel, monthly and annual variation*. Estuar. Coast. Shelf Sci., 2001. **52**: 669-687.

3. Fishbase, *Fishbase:* Urophycis tenuis - *White hake.* http://www.fishbase.org/Summary/SpeciesSummary.cfm?genusname=Urophycis&speciesname=tenuis, 2004.
4. Chang, S., W.W. Morse, and P.L. Berrien, *Essential fish habitat source document: white hake,* Urophycis tenuis, *life history and habitat characteristics.* NOAA Technical Memorandum, 1999. NMFS-NE 136: v + 23 pp.
5. Lang, K.L., et al., *The use of otolith microstructure in resolving issues of first year growth and spawning seasonality of white hake,* Urophycis tenuis, *in the Gulf of Maine-Georges Bank region.* U.S. Fish. Bull., 1996. **94**: 170-175.
6. Markle, D.F. and L.A. Frost, *Comparative morphology, seasonality, and a key to planktonic fish eggs from the Nova Scotian Shelf.* Can. J. Zool., 1985. **63**: 246-257.
7. Heck Jr, K.L., et al., *Fishes and decapod crustaceans of Cape Cod eelgrass meadows: species composition and seasonal abundance patterns.* Estuaries, 1989. **12**: 59-65.
8. Markle, D.F., D.A. Methven, and L.J. Coates-Markle, *Aspects of spatial and temporal co-occurrence in the life history stages of the sibling hakes,* Urophysis chuss *and* Urophysis tenuis *(Pisces: Gadidae).* Can. J. Zool., 1982. **60**: 2057-2078.
9. Langton, R.W. and R.E. Bowman, *Food of fifteen Northwest Atlantic gadiform fishes.* NOAA Tech. Rep., 1980. NMFS SSRF-740: 23 pp.
10. Bowman, R.E., *Food of 10 species of northwest Atlantic juvenile groundfish.* U.S. Fish. Bull., 1981. **79**: 200-206.
11. O'Brien, L., J. Burnett, and R.K. Mayo, *Maturation of nineteen species of finfish off the northeast coast of the United States, 1985-1990.* NOAA Tech. Rep., 1993. NMFS 113: 1-66.
12. Beachman, T.D. and S.J. Nepszy, *Some aspects of the biology of white hake,* Urophysis tenuis, *in the southern Gulf of St. Lawrence.* J. Northw. Atl. Fish. Sci., 1980. **1**: 49-54.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Atlantic silverside *Menidia menidia*	Source
Abiotic Factors		
Temperature	- 1 to 16 °C - 1 to 22 °C offshore in Cape Hatteras	[1] [2]
Salinity	- 11 to 33 ‰	[1]
Oxygen	- young-of-year have low tolerance of low dissolved-O_2	[3]
Substrate preference	- pelagic in shallow coastal shorelines, estuaries and intertidal creeks over a variety of substrates: mud, sand , gravel - inshore when water warms, offshore ~50 km during winter - caught inshore from April to January	[4], [1] [2] [1]
Water current and tides	- no data found	
Use of cover	- can be associated with eelgrass and sea lettuce	[5]
Biotic Factors		
Spawning time	- June in PEI - late June to early July in Annapolis River, NS - late spring to early summer in Long Island Sound	[6] [7] [8]
Spawning habitat	- nearshore nursery, spawning in intertidal estuarine areas including marsh creeks	[1], [3]
Eggs	- demersal, 0.08 to 1.2 mm in diameter, spherical - hatch in 8 days at 22 to 29 °C	[9] [3]
Foods	- copepods, mysids, shrimps, small squids, marine worms, and eggs - Insects are second most important prey in Bay of Fundy - barnacle nauplii, small decapods, amphipods, cladocerans, algae, diatoms, mollusc larvae in the Gulf of Maine	[10] [11] [12],[13], [4]
Other	- size at maturation: 50 to 80 mm - mature at age 1 in Annapolis River, NS - growth rate of ~5 mm/month in Annapolis River - rapid growth ~20 mm/month in Gulf of Maine - active primarily during the day	[3] [7] [7] [14] [1]

References

1. Casselman, J. and D.A. Methven, *A comparison of the seasonal occurrences of nearshore fishes in the lower Bay of Fundy: Passamaquoddy Bay, Musquash area and approaches to Saint John Harbour*. 2004, University of New Brunswick: Saint John, NB. Unpublished report done for DFO.
2. Conover, D.O. and S.A. Murawski, *Offshore winter migration of the Atlantic silverside,* Menidia menidia, *in a New England estuary.* Estuaries, 1982. **5**: 275-286.

3. Able, K.W. and M.P. Fahay, *The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight*. 1998, New Brunswick, New Jersey: Rutgers University Press. 342 pp.
4. Bigelow, H.B. and W.C. Schroeder, *Fishes of the Gulf of Maine*. Revision 1.1 2002, Online Edition ed. Fish. Bull. 74; Fish. Bull. Fish and Wildlife Serv. 53; Contribution (Woods Hole Oceanographic Institution) No. 592. 2002, Washington: United States Government Printing Office. viii + 577 pp.
5. Able, K.W., et al., *Fishes of polyhaline estuarine shores in Great Bay-Little Egg Harbor, New Jersey: a case study of seasonal and habitat influences*. Pages 335-353. In *Estuarine Shores: Evolution, environments and human alterations*, K.F. Nordstrom and C.T. Roman, Editors. 1996, Wiley: Chichester, England.
6. Needler, A.W.H., *A preliminary list of the fishes of Malpeque Bay*. Proc. N.S. Inst. Sci., 1940. **1939-40, 20**: 33-41.
7. Jessop, B.M., *Aspects of the life history of the Atlantic silverside (*Menidia menidia*) of the Annapolis River, Nova Scotia*. Can. Man. Rep. Fish. Aquat. Sci., 1983. **1694**: 41 pp.
8. Middaugh, D.P. and T. Takita, *Tidal and diurnal spawning cues in the Atlantic silverside,* Menidia menidia. Environ. Biol. Fishes, 1983. **8**: 97-104.
9. Bayliff, W.H.J., *The life history of the silverside* Menidia menidia. Cheakepeake Biol. Lab. Publ., 1950. **90**: 27 pp.
10. Scott, W.B. and M.G. Scott, *Atlantic fishes of Canada*. Can. Bull. Fish. Aquat. Sci. 219. 1988, Ottawa: University of Toronto Press; Minister of Fisheries and Oceans; Canadian Government Publishing Centre. xxx + 731 pp.
11. Salinas, I. *The feeding biology of* Menidia menidia *inhabiting a mud-flat ecosystem*. in *Fundy Environmental Studies Committee Annual Workshop*. 1979. St. Andrews, NB: Atlantic Provinces Inter-University Committee on the Sciences.
12. Bengston, D.A., *Resource partitioning by* Menidia menidia *and* Menidia berrylina *(Osteichthyes: Atherinidae)*. Mar. Ecol. Prog. Ser., 1984. **18**: 21-30.
13. Crawford, P. and G.R. Daborn, *Seasonal variations in body size and fecundity in a copepod of turbid estuaries*. Estuaries, 1986. **9**: 133-141.
14. Conover, D.O. and M.R. Ross, *Patterns in seasonal abundance, growth and biomass of the Atlantic silverside,* Menidia menidia*, in a New England estuary*. Estuaries, 1982. **5**: 275-286.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Rainbow smelt *Osmerus mordax mordax*	Source
Abiotic Factors		
Temperature	- 0 to 17.2 °C - in freshwater prefer 7.2 °C	[1] [2]
Salinity	- 11 to 32 ppt	[1]
Oxygen	- no data found	
Substrate preference	- schooling pelagic, inshore (< 1.2 m) over a variety of substrates: mud, sand, gravel - bays and estuaries - estuaries during cold months, into deeper waters during summer - anadromous, freshwater, brackish, marine, depth range 0 - 150 m	[3], [1] [4] [5] [6]
Water current and tides	- important in larval retention	[7]
Use of cover	- some association with eelgrass beds in the Weweantic River, Massachusetts - adults and juveniles congregates	[8] [5], [9]
Biotic Factors		
Spawning time	- June on southern shores of Gulf of St. Lawrence - late April to May in Miramichi - late February in southern Massachusssets	[10] [5] [8]
Spawning habitat	- ascends freshwater streams to spawn	[1]
Eggs	- demersal attach to bottom gravel, 0.9 to 1.2 mm in diameter - hatching in 8 (at 20 °C) to 63 days (at 4 °C)	[10] [7]
Foods	- amphipods, euphausiids, mysids, shrimps, marine worms and small fish in the Gulf of Maine - prey primarily on shellfish, squid, annelid worms and crabs in Woods Hole	[11] [10]
Other	- size at maturation: 12 cm - rapid growth ~2 cm/year - more active at night, sensitive to light - migrates up to 1,000 km upstream in rivers	[4] [5] [1], [4] [6]

References

1. Casselman, J. and D.A. Methven, *A comparison of the seasonal occurrences of nearshore fishes in the lower Bay of Fundy: Passamaquoddy Bay, Musquash area and approaches to Saint John Harbour*. 2004, University of New Brunswick: Saint John, NB. Unpublished report done for DFO.
2. Hart, J.L. and R.G. Fergerson, *The American smelt.* Trade News, 1966. **18**: 22-23.
3. Dadswell, M.J., *Further new localities for certan coldwater fishes in eastern Ontario and western Quebec.* Can. Field Natur., 1975. **89**: 447-450.
4. Scott, W.B. and E.J. Crossman, *Freshwater fishes of Canada.* Fish. Res. Board Can. Bull., 1973. **184**.
5. McKenzie, R.A., *Smelt life history and fishery in the Miramichi River, New Brunswick.* Fish. Res. Board Can. Bull., 1964. **144**: 77 pp.

6. Fishbase, *Fishbase:* Osmerus mordax mordax *- Atlantic rainbow smelt.* http://www.fishbase.org/Summary/SpeciesSummary.cfm?genusname=Osmerus&speciesname=mordax%20mordax, 2004.
7. Able, K.W. and M.P. Fahay, *The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight*. 1998, New Brunswick, New Jersey: Rutgers University Press. 342 pp.
8. Crestin, D.S., *Some aspects of the biology of adults and early life stages of the rainbow smelt,* Osmerus mordax, *from the Weweantic River estuary, Wareham-Marion, Massachussets, 1968.*, Thesis in *Biology*. 1973, University of Massachussets: Amherst, New Jersey. 108 pp.
9. Clayton, G.R., *Reproduction, first year growth, and distribution of anadromous rainbow smelt,* Osmerus mordax, *in the Parker River and Plum Island Sound estuary, Massachusetts.*, Thesis in *Biology*. 1976, University of Massachusetts: Amherst, Massachussets. 105 pp.
10. Bigelow, H.B. and W.C. Schroeder, *Fishes of the Gulf of Maine*. Revision 1.1 2002, Online Edition ed. Fish. Bull. 74; Fish. Bull. Fish and Wildlife Serv. 53; Contribution (Woods Hole Oceanographic Institution) No. 592. 2002, Washington: United States Government Printing Office. viii + 577 pp.
11. Scott, W.B. and M.G. Scott, *Atlantic fishes of Canada*. Can. Bull. Fish. Aquat. Sci. 219. 1988, Ottawa: University of Toronto Press; Minister of Fisheries and Oceans; Canadian Government Publishing Centre. xxx + 731 pp.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Atlantic herring *Clupea harengus*	Source
Abiotic Factors		
Temperature	- 1 to 18 °C - 2.5 to 16 °C - 8 to 12 °C in Gulf of Maine - upper lethal for juveniles 19.5 to 21.2 °C, lower lethal of -1.1 °C, preferred 8 to 12 °C - adults spawn at 7 to 15 °C	[1] [2] [3] [4] [4]
Salinity	- 21 to 32 ‰ - juveniles salinity preference of 26 to 32 ‰ - adults generally occur in water > 28 ‰	[2], [5] [4] [4]
Oxygen	- no data found	
Substrate preference	- schooling, pelagic over sand, gravel and mud - juveniles form large schools in coastal waters - juveniles spend summers in inshore areas off Maine and New Brunswick	[2] [4] [4]
Water current and tides	- lays eggs in strong tidal current areas - may assist in larval dispersal	[4] [6]
Use of cover	- no information found	
Biotic Factors		
Spawning time	- April to November in Atlantic Canada - August to October in the coastal waters of Maine	[7] [8]
Spawning habitat	- coastal waters - gravel is preferred substrate	[8] [9]
Eggs	- laid on variety of substrates: boulders, rocks, gravel, sand, shell fragments, and macrophytes - demersal, 1 to 1.4 mm in diameter - hatching in 10 to 15 days - hatching: 10 to 30 days depending on temperature	[4] [10] [1] [11]
Foods	- barnacle larvae & cladocerans in spring, copepods & euphausiids in the fall - copepods, fish eggs, pteropods, mollusc larvae & fish larvae - zooplankton & crustaceans	[12] [7] [13]
Other	- large migrations up & down Atlantic coast throughout the year - 25 to 28 cm TL at maturity (3-4 yrs) - growth rate ~5 cm/year for first 5 years, ~1 cm/year after 5 years - March to May (30 to 50 mm TL) widely distributed in Bay of Fundy - active mostly during the day - pelagic larvae for 4 to 8 months	[7] [14],[15] [16],[17] [5] [2] [4]

References

1. Fishbase, *Fishbase:* Clupea harengus, *Atlantic herring.* http://www.fishbase.org/Summary/SpeciesSummary.cfm?ID=24&genusname=Clupea&speciesname=harengus, 2004.
2. Casselman, J. and D.A. Methven, *A comparison of the seasonal occurrences of nearshore fishes in the lower Bay of Fundy: Passamaquoddy Bay, Musquash area and approaches to Saint John Harbour*. 2004, University of New Brunswick: Saint John, NB. Unpublished report done for DFO.
3. Stickney, A.P., *Orientation of juvenile Atlantic herring (*Clupea harengus*) to temperature and salinity.* Pages 323-242. In *Proceedings of the FAO conference on fish behavior in relation to fishing techniques and tactics*. 1969.
4. Reid, R.N., et al., *Essential fish habitat source document: Atlantic herring,* Clupea harengus, *life history and habitat characteristics.* NOAA Tech. Memo. Rep., 1999. NMFS-NE-126: 48 pp.
5. Bigelow, H.B. and W.C. Schroeder, *Fishes of the Gulf of Maine*. Revision 1.1 2002, Online Edition ed. Fish. Bull. 74; Fish. Bull. Fish and Wildlife Serv. 53; Contribution (Woods Hole Oceanographic Institution) No. 592. 2002, Washington: United States Government Printing Office. viii + 577 pp.
6. Stephenson, R.L. and M.J. Power, *Semidiel vertical movements in Atlantic herring* Clupea harengus *in the Georges Bank area.* Mar. Ecol. Prog. Ser., 1988. **50**: 3-11.
7. Scott, W.B. and M.G. Scott, *Atlantic fishes of Canada*. Can. Bull. Fish. Aquat. Sci. 219. 1988, Ottawa: University of Toronto Press; Minister of Fisheries and Oceans; Canadian Government Publishing Centre. xxx + 731 pp.
8. Stephenson, D.K., *Spawning locations and times for Atlantic herring on the Maine coast.* Repp. Proc.-Verb. Reun. Cons. Int. Explor. Mer., 1989. **62**: 323-342.
9. Drapeau, G., *Sedimentology of herring spawning grounds on Georges Bank.* Int. Comm. Northw. Atl. Fish. Res. Bull., 1973. **10**: 151-162.
10. Fahay, M.P., *Guide to the early stages of marine fishes occurring in the western North Atlantic Ocean: Cape Hatteras to the southern Scotian Shelf.* J. Northw. Atl. Fish. Sci., 1983. **4**: 1-423.
11. Able, K.W. and M.P. Fahay, *The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight*. 1998, New Brunswick, New Jersey: Rutgers University Press. 342 pp.
12. Battle, H.I., *Laboratory feeding of the herring.* Biol. Bd. Can. Ann. Rep. for 1933, 1934: 14-15.
13. Blaxter, J.H.S. *The effect of light intensity on the feeding ecology of herring.* In *Light as an Ecological Factor: Symposium of The British Ecological Society, 30 March - 1 April, 1965*. 1966. Cambridge: Wiley, New York.
14. O'Brien, L., J. Burnett, and R.K. Mayo, *Maturation of nineteen species of finfish off the northeast coast of the United States, 1985-1990.* NOAA Tech. Rep., 1993. NMFS 113: 1-66.
15. Boyar, H.C., *Age, length and gonadal stages of herring from Georges Bank and the Gulf of Maine.* Int. Comm, Northw. Atl. Fish. Res. Bull., 1968. **5**: 49-61.

16. Pentilla, J.A., G.A. Nelson, and J.M. Burnett III, *Guidelines for estimating lengths at age for 18 northwest Atlantic finfish and shellfish species*. NOAA Tech. Memo. NMFS-F/NEC-66. 1989, NOAA. 39 pp.

17. Jean, Y., *A study of spring and fall spawning herring (Clupea harengus) at Grande Riviere, Bay of Chaleur, Quebec*. Dep. Fish. Que. Contrib., 1956. **49**: 76 pp.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Alewife *Alosa pseudoharengus*	Source
Abiotic Factors		
Temperature	- 8.5 to 16 °C - 2 to 17 °C along US Atlantic coast - upper lethal for eggs of 29.7 °C - juveniles prefer 20 to 22 °C	[1] [2], [3] [4] [4]
Salinity	- 22 to 32 ‰ - juveniles prefer 4 to 6 ‰ - during spawning migration adults highly tolerant of salinity changes	[1] [4] [4]
Oxygen	- no data found	
Substrate preference	- nearshore to offshore waters in the Bay of Fundy, Gulf of Maine - shallow nearshore waters during summer, offshore during winter - pelagic over sand, gravel and mud	[5] [5] [1]
Water current and tides	- assumed important for larval dispersal	
Use of cover	- no data found	
Biotic Factors		
Spawning time	- late April or May in Maine & Atlantic Canada - March in Chesapeake Bay	[6] [6]
Spawning habitat	- occurs in freshwater rivers, streams and ponds - in lakes and quiet stretches of rivers - some evidence of return to natal rivers to spawn - spawning starts between 13 to 15 °C and up to 27 °C	[7] [8] [4] [4]
Eggs	- semi-demersal to pelagic depending on salinity, 0.8 to 1.27 mm in diameter - average of 60,000-100,000 eggs/female - high sediment load causes egg mortality - incubation time from 2 days (at 29 °C) to 15 days (at 7.2°C)	[9], [10] [11] [4] [4]
Foods	- copepods, amphipods, mysids, fish eggs & small fishes - juveniles feed on cladocerans, zooplankton, copepods, amphipods and insects	[12] [6]
Other	- size at maturity in Atlantic Canada: 25 to 31 cm, 3 to 5 years - more active at nights - juveniles caught in < 1.2 m water - fry descend in summer and autumn or even as late as November or December - nearshore nursery habitats	[13],[12] [1] [1] [8] [1]

References

1. Casselman, J. and D.A. Methven, *A comparison of the seasonal occurrences of nearshore fishes in the lower Bay of Fundy: Passamaquoddy Bay, Musquash area*

and approaches to Saint John Harbour. 2004, University of New Brunswick: Saint John, NB. Unpublished report done for DFO.

2. Milstein, C.B., *Abundance and distribution of juvenile* Alosa *species off southern New Jersey*. Trans. Amer. Fish. Soc., 1981. **110**: 306-309.
3. Neves, R.J., *Offshore distribution of alewife,* Alosa pseudoharengus, *and blueback herring,* Alosa aestivalis, *along the Atlantic coast*. U.S. Fish. Bull., 1981. **79**: 473-485.
4. Able, K.W. and M.P. Fahay, *The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight*. 1998, New Brunswick, New Jersey: Rutgers University Press. 342 pp.
5. Stone, H.H. and B.M. Jessop, *Seasonal distribution of river herring* Alosa pseudoharengus *and* A. aestivalis *off the Atlantic coast of Nova Scotia*. U.S. Fish. Bull., 1992. **90**: 376-389.
6. Bigelow, H.B. and W.C. Schroeder, *Fishes of the Gulf of Maine*. Revision 1.1 2002, Online Edition ed. Fish. Bull. 74; Fish. Bull. Fish and Wildlife Serv. 53; Contribution (Woods Hole Oceanographic Institution) No. 592. 2002, Washington: United States Government Printing Office. viii + 577 pp.
7. Fishbase, *Fishbase: Anadromous Fishes - ALEWIFE*. http://www.fisheries.vims.edu/anadromous/alewife.htm, 2004.
8. Whitehead, P.J.P., *FAO species catalogue. V. 7, Clupeoid fishes of the world (suborder Clupeoidei) : an annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. Part 1, Chironcentridae, Clupeidae, Pristigasteridae*. FAO Fisheries Synopsis; 125 (7-1). 1985, Rome: FAO.
9. Mansueti, R.J., *Alewife herring eggs and larvae reared successfully in lab*. Md. Tidewater News, 1956. **13**: 2-3.
10. Jones, P.W., F.D. Martin, and J.D. Hardy, *Development of fishes in the Mid-Atlantic Bight: An atlas of egg, larval and juvenile stages. Vol. 1: Acipenseridae through Ictaluridae*. Chesapeake Biological Laboratory, Center for Environmental and Estuarine Studies, University of Maryland. 1978, Washington: U.S. Government Printing Office.
11. Mansueti, R.J. and J.D. Hardy, *Development of fishes of the Chesapeake Bay Region Part 1*. 1967, Nat. Res. Inst., University of Maryland: Baltimore, Maryland. 202 pp.
12. Scott, W.B. and M.G. Scott, *Atlantic fishes of Canada*. Can. Bull. Fish. Aquat. Sci. 219. 1988, Ottawa: University of Toronto Press; Minister of Fisheries and Oceans; Canadian Government Publishing Centre. xxx + 731 pp.
13. Jessop, B.M., *Aspects of the life history of the Atlantic silverside (*Menidia menidia*) of the Annapolis River, Nova Scotia*. Can. Man. Rep. Fish. Aquat. Sci., 1983. **1694**: 41 pp.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Grubby, Little sculpin *Myxocehpalus aenaeus*	Source
Abiotic Factors		
Temperature	- 1 to 15.5 °C - 0 and 21°C	[1] [2]
Salinity	- no data found	
Oxygen	- no data found	
Substrate preference	- brackish, marine - demersal over sand, gravel & mud - low tide mark down to 27 m, juveniles in less the 1.2 m depth (common in eelgrass beds)	[2] [1] [1], [3]
Water current and tides	- assumed important for larval dispersal	
Use of cover	- juveniles show some association with eelgrass beds	[4]
Biotic Factors		
Spawning time	- fall into winter in Newfoundland - March to June on Georges Bank and New Jersey	[5] [3]
Spawning habitat	- begins in coastal waters and ends offshore	[3]
Eggs	- demersal, spherical, transparent, adhesive, 1.5 to 1.7 mm in diameter - larvae hatches after 40 to 57 days	[3] [3]
Foods	- shrimp, crabs, copepods, snails, molluscs, sea squirts, sea urchins and young fishes	[4]
Other	- very little information on migration available - more active at night	[3] [1]

References

1. Casselman, J. and D.A. Methven, *A comparison of the seasonal occurrences of nearshore fishes in the lower Bay of Fundy: Passamaquoddy Bay, Musquash area and approaches to Saint John Harbour*. 2004, University of New Brunswick: Saint John, NB. Unpublished report done for DFO.
2. Fishbase, *Fishbase:* Myoxocephalus aenaeus *- Grubby*. http://www.fishbase.org/Summary/SpeciesSummary.cfm?genusname=Myoxocephalus&speciesname=aenaeus, 2004.
3. Able, K.W. and M.P. Fahay, *The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight*. 1998, New Brunswick, New Jersey: Rutgers University Press. 342 pp.
4. Bigelow, H.B. and W.C. Schroeder, *Fishes of the Gulf of Maine*. Revision 1.1 2002, Online Edition ed. Fish. Bull. 74; Fish. Bull. Fish and Wildlife Serv. 53; Contribution (Woods Hole Oceanographic Institution) No. 592. 2002, Washington: United States Government Printing Office. viii + 577 pp.
5. Ennis, G.P., *Occurrence of the little sculpin,* Myxocephalus aenaeus, *in Newfoundland waters*. J. Fish. Res. Bd. Can., 1969. **27**: 1689-1694.

Species Life Requirements/Habitats: Musquash Estuary		
Species	American Eel *Anguilla rostrata*	Source
Abiotic Factors		
Temperature	- when water temperatures reach 6 to 8 °C elvers arrive from their sea journey to travel upstream	[1]
	- less active when water temperature drops below 11 °C in the fall, movement into deeper waters at this time to spend winter, sensitive to harsh winter conditions	[1], [2]
Salinity	- mature adults travel from freshwater into full salinity	[1]
	- elvers travel from full salinity to freshwater, some may remain in estuarine and coastal waters	[1]
	- whips (juveniles larger than elvers) are able to withstand abrupt changes in salinity	[2]
Oxygen	- no data found	
Substrate preference	- found in estuaries, coastal streams, rivers, & landlocked lakes	[2]
	- elvers may be found in wide range of coastal habitats, including marshes, tidal flats, harbours, barrier beach ponds, coastal rivers, creeks and streams	[2]
	- spend 5 to 10 yrs in freshwater or more before migrating for spawning	[1]
	- adults are strongly sedentary & have relatively small home ranges	[1]
Water current and tides	- elvers peak arrival from sea may occur during spring tides at night	[1]
	- the Gulf Stream is important in transport of larvae northwards from spawning area in the Sargasso Sea	[1]
Use of cover	- immature adults generally active at nights, retire to burrows in muddy bottoms or other cover during day	[1]
	- burrow into mud or hibernate in burrows with ventilation holes during the winter	[2]
Biotic Factors		
Spawning time	- size at maturity varies geographically and according to sex: males typically smaller than females	[1]
	- spawning migration occurs between August & December mostly at dusk and at night	[1]
	- migration to spawning area takes about 2 to 3 months	[2]
	- spawning peaks between January and March	[1], [2]
Spawning habitat	- catadromous: adults migrate downstream to sea to spawn in the Western part of the Sargasso Sea with eels from all geographic areas	[1]
	- accumulates fat before feeding ceases and gut degenerates during migration, eyes enlarges	[1], [2]
	- presumed adults die after spawning	[1]
Eggs	- slightly elliptical, range 0.59 to 1.25 mm in diameter	[2]
	- larger females spawn more eggs than do smaller ones	[1]
	- a 724 mm length female weighing 755 g estimated to contain 2.6 million eggs	[1]
	- eggs hatches into willow-leaf-shaped larvae	[1]

	(leptocephalus) drift northwards in the Gulf Stream spending a year or more before entering Canadian waters and metamorphosing into a typical eel shape	
Foods	- voracious carnivores, eating a variety of fishes and invertebrates: insects, snails, worms, etc.	[1]
	- acute sense of smell assist in finding food	[1]
Other	- commercially important in Musquash Estuary, both adults (minimum size: 20 cm) and elvers are targeted between May and October, peaking in June & July	[3]
	- immature adult eels range in colour from yellowish to greenish or olive-brown, migrate to estuaries in spring	[1]
	- sexually maturing eels during migration have a metallic sheen, bronze or black on the back & silvery below, females may exceed 1,000 mm length & > 1 kg	[1]
	- newly developed eels develop pigmentation as they near the coast and are called elvers (40 to 70 mm)	[1]
	- elvers enter streams in large numbers during early May and June when water temperatures reach 6 to 8 °C	[1]
	- elvers do not return to natal streams but are dependent on currents to get to suitable streams, numbers believed to be dependent on river system size & productivity	[1], [3]
	- elvers may be associated with eelgrass beds	[2]
	- sex determination may be environmentally influenced: more males when population density is high	[1]
	- males found almost exclusively in salty or brackish waters	[2]
	- no known relationship between size of adult stock in a river and the future return of elvers	[1]
	- annual return of elvers varies between years & may be influenced by environmental conditions at sea	[1] [3]
	- elvers experience high natural mortality	[1]

References

1. Jessop, B.M., *The American Eel.* In *Underwater World.* 1984, Fisheries and Oceans Canada. Communications Directorate: Ottawa, ON. 6 pp.
2. Able, K.W. and M.P. Fahay, *The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight.* 1998, New Brunswick, New Jersey: Rutgers University Press. 342 pp.
3. Jessop, B.M., *Eel fishes in the Maritimes (Anguilla rostrata)*, in *DFO Atlantic Fisheries: Stock Status Report 96/14E.* 1996, Department of Fisheries & Oceans Canada: Halifax, NS. 4 pp.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Ocean pout, Wrymouth, Eel pout, Muttonfish *Macrozoarces americanus*	Source
Abiotic Factors		
Temperature	- preferred < 10 °C - adults usually found in 3 to 14 °C	[1] [1]
Salinity	- juveniles commonly found in > 25 ‰	[2]
Oxygen	- limited tolerance of hypoxic and anoxic conditions	[3]
Substrate preference	- benthic in open and rough habitats, form schools, considered as non-migratory but moves to remain at preferred temperatures - hatchlings remain near nest	[1] [4]
Water current and tides	- no data found	
Use of cover	- juveniles shallow found in shallow coastal waters around rocks and attached algae - over softer sediments adults may bury themselves	[4] [5]
Biotic Factors		
Spawning time	- fall with mid-winter hatching	[4]
Spawning habitat	- protected habitats, such as rock crevices and man-made artefacts	[1]
Eggs	- builds nest, guarded by one or both parents - fertilized internally, demersal, laid in gelatinous masses - development is about 2-3 months, but temperature dependent - size (diameter) varies seasonally - low fecundity, 1300 to 4200 eggs/spawning period	[1] [4] [6] [6] [6]
Foods	- "ambush predator" - juveniles feed on harpacticoid copepods, gammarids and polychaetes - adults feed on polychaetes, mollusks, crustaceans, and echinoderms	[5] [7] [6]
Other	- all life stages found in Passamaquoddy Bay - after hatching larvae stays near bottom - juveniles grow to 6-8 cm TL by their first summer - northern males mature at a mean length of 30.3 cm and females at 26.2 cm - cease feeding prior to and during spawning	[2] [4] [6] [8] [6]

References

1. Steimle, F.W., et al., *Essential Fish Habitat Source Document: Ocean Pout, Macrozoarces americanus, Life History and Habitat Characteristics.* NOAA Tech. Memo. Rep., 1999. NMFS-NE-129: 26 pp.
2. Jury, S.H., et al., *Distribution and abundance of fishes and invertebrates in North Atlantic estuaries*, in *ELMR Rep. No. 13.* 1994, NOAA/NOS Strategic Environmental Assessments Division: Silver Spring, MD. 221 pp.
3. Azarovitz, T.R., et al., *Effects on finfish and lobster.* Pages 295-314. In *Oxygen depletion and associated benthic mortalities in the New York Bight, 1976.*, R.L.

Swanson and C.J. Sindermann, Editors. 1979, U.S. Dep. Commer. Natl. Oceanic Atmos. Adm.: Rockville, MD.

4. Bigelow, H.B. and W.C. Schroeder, *Fishes of the Gulf of Maine*. Revision 1.1 2002, Online Edition ed. Fish. Bull. 74; Fish. Bull. Fish and Wildlife Serv. 53; Contribution (Woods Hole Oceanographic Institution) No. 592. 2002, Washington: United States Government Printing Office. viii + 577 pp.

5. Auster, P.J., R.J. Malatesta, and S.C. LaRosa, *Patterns of microhabitat utilization by mobile megafauna on the southern New England (USA) continental shelf and slope.* Mar. Ecol. Prog. Ser., 1995. **127**: 77-85.

6. Olsen, Y.N. and D. Merriman, *Studies of the marine resources of southern New England. IV. The biology and economic importance of the ocean pout,* Macrozoarces americanus *(Bloch and Schneider).* Bull. Bingham Oceanogr. Collect., 1946. **9**: 1-184.

7. Keats, D.W. and D.H. Steele, *Food of 0-group ocean pout (*Macrozoarces americanus*) in eastern Newfoundland: the importance of harpacticoid copepods.* J. Fish Biol., 1993. **42**: 45-148.

8. O'Brien, L., J. Burnett, and R.K. Mayo, *Maturation of nineteen species of finfish off the northeast coast of the United States, 1985-1990.* NOAA Tech. Rep., 1993. NMFS 113: 1-66.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Harbour Seal *Phoca vitulina*	Source
Abiotic Factors		
Temperature	- no information found	
Salinity	- will enter estuaries and the lower reaches of rivers throughout their range	[1]
Oxygen	- can spend up to one hr under water	[1]
Substrate preference	- close to shore - usually stay in the same area all year round	[1] [2]
Water current and tides	- basking on low lying rocks, sand beaches, reefs, piers or ice at low tide - haulout time is dependent on tides and prevailing weather patterns: out of water at low tide, in water during inclement weather	[3] [1]
Use of cover	- will dive into water when disturbed	[1]
Biotic Factors		
Breeding time	- mating takes place after weaning (mid-June to August) - during mating season males are very aggressive and may lose up to 25% of body weight	[2] [2]
Breeding habitat	- takes place in the water	[3]
Young pups	- a single pup is born mid-May to July - at birth 65 to 100 cm and 8 to 12 kg - weaned after four weeks, generally leave their birth site to explore their new habitat - sometimes preyed upon by foxes and birds of prey	[2] [3] [2] [2]
Foods	- rockfish, herring, cod, mackerel, flounder, salmon, molluscs, squid, clams, shrimp and octopus - opportunistic feeders and their diet varies with season	[3] [4]
Other	- non-migratory - on land gregarious, aggregates in large numbers on beaches and ice - individual harbour seals can be identified year after year, markings on coats do not change - moult takes place in July and August - gets fresh water solely from the food - males range from 1.4 to 1.9 m, and weigh from 70 to 130 kg; females slightly smaller - females reach sexual maturity at ~3 to5 yrs, males between 5 and 6 yrs - easily affected by habitat disturbance and alteration	[3] [3] [2] [2] [2] [4] [4] [4]

References

1. Associates, Golder, *NB Power Coleson Cove Refurbishment Project: Comaprative ecological risk assessment pf spill of Orimulsion of fuel oil #6 in the Bay of Fundy*. 2002, Report for NB Power.
2. OSC-MUN, *Harbour seals*. http://www.osc.mun.ca/seals/harbour.html, 2004.

3. Jefferson, T.A., S. Leatherwood, and M.A. Webber, *Marine mammals of the world*. FAO Species Identification Guide. 1993, Rome: Food and Agricultural Organization of the United Nations. viii + 320 pp.
4. Phagophilus, *Harbour Seal* - Phoca vitulina. http://www.pagophilus.org/harbour.html, 2004.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Common eider (American Race) *Somateria mollissima dresseri*	Source
Abiotic Factors		
Temperature	- well adapted to life in frigid waters - under extreme cold during winter they become inactive, stop feeding and gather in large groups - ↑ peripheral vasoconstriction occurs in cold water	[1] [1] [2]
Salinity	- no information found	
Oxygen	- no information found	
Substrate preference	- closely tied to marine habitats, often breed & nest in colonies along marine coasts - undergo moult in open water leads in pack ice (polynyas) & along leeward sides of islands in arctic & sub-arctic waters as well as in their wintering ice-free waters in New England & Maritimes - large aggregations may occur during spring migration in areas immediately south of arctic ice & in open leads - observed in 1999 in Musquash at Five Fathon Hole Harbour and Musquash Ledges	[1] [1] [1] [3]
Water current and tides	- no information found	
Cover	- no information found	
Biotic Factors		
Reproduction time	- once per year, starting May or June - courtship intense during spring & eiders may form pairs (some may show long-term pair bonds)	[4] [1]
Reproduction habitat	- on island from southcentral coasts of Labrador, Newfoundland, along Quebec North Shore, St. Lawrence Estuary, Atlantic & Bay of Fundy coasts of NS and NB, along coast of MA & ME - in the Musquash area, about 20 nests were observed in 1999 on Gooseberry Island - frequently nests in dense colonies, typically return to natal areas and even to same nest - nest built on ground and lined with thick layer of down from female breast	[5] [3] [1] [1]
Reproduction	- length of incubation 25 to 30 days - clutch size: 4 to 6 (average 4) - days to fledge: 60-75; most lost to predation, exposure & starvation during first two weeks of life - male eiders do not attain full plumage and sexually maturity until 3 yrs old, while females take 2 yrs - female feeds very little during incubation and loses up to 40% body weight - survival of ducklings is improved by the formation of large aggregations of duckling and hens (crèches)	[4] [1], [4] [1], [4] [1] [1] [1]
Food	- almost exclusively aquatic invertebrates (mussels, clams, scallops, sea urchins, starfish, & crabs); lesser quantities of fish - feed mostly during the day, diving 3 to 20 m	[1], [4] [1]

Migration	- migration not well documented, likely along north coast of Gulf of St. Lawrence moving north to south coast of Labrador	[5]
	- wintering off southwestern NS & New England and as far south as New York, greatest numbers in Maine	[1],[6],[7]
	- peak movement takes place during latter half of November	[7],[8]
	- spring migration from wintering areas off New England move through NB and NS in early April arriving in St. Lawrence in late April	[9]
	- limited information exist about overland migration to the St. Lawrence Estuary	[9]
	- by early May only local breeders are evident	[7]
	- birds from NB and Maine are relatively sedentary with wintering range extending into Massachusetts	[5]
Other	- largest duck in northern hemisphere	[1]
	- adult weighs 1300 to 2600 g (2.8 to 5.9 lbs) & is over 50 to 70 cm long, can live up to 20 yrs	[1]
	- males somewhat larger than females	[1]
	- adult male plumage during fall to summer is mostly white on upper parts except for a black crown; overall plumage during mid-summer to early fall is dark brown to blackish	[1]
	- adult female plumage is mostly dark to rusty brown with fine black barrings on its sides, more muted plumage during mid-summer to early fall	[1]
	- four races recognized in North America (American Race present in Maritimes)	[1]
	- unable to fly during moult for 3 to 4 weeks	[1]
	- have annual survival rates of 80 to 95%	[1]
	- population of American Race appears generally stable or increasing	[1]
	- susceptible to harvest (eggs, adult birds and down) pressure, as well as environmental threats and disease outbreaks	[1]
	- have limited ability to compensate for hunting mortality through increased recruitment or survival	[5]
	- fledgling survival increases when gull control is active	[10]
	- increasing avian predators may result in negative impact on eider population through ↓ fledgling survival	[5]

References

1. SDVJ, *Sea Duck Information Series: Common Eider* (Somateria mollissima), in *Information Sheet*. 2004, Sea Duck Joint Venture. 2 pp.
2. Jenssen, B.M., M. Ekker, and C. Bech, *Thermoregulation in winter-acclimatized common eiders (*Somateria mollissima*) in air and water*. Can. J. Zool., 1989. **67**: 669-705.
3. Deichmann, H., *A. survey of bird life in the Musquash Estuary on the Bay of Fundy New Brunswick*. Prepared for the Conservation Council of New

Brunswick. 1999, Conservation Council of New Brunswick. Fredericton, N. B. 69 pp.

4. Gough, G.A., J.R. Sauer, and M. Iliff, *Patuxent Bird Identification Infocenter. Version 97.1. http://www.mbr-pwrc.usgs.gov/Infocenter/infocenter.html*. 1998, Patuxent Wildlife Research Center: Laurel, MD.
5. Anonymous, *Sea Duck Joint Venture: Species status report by Continental Technical Team*. 2003, North American Wetlands Conservation Council: Arlington, Virginia. 85 pp.
6. Reed, A., *Migration, homing, and mortality of breeding female eiders* Somateria mollissima dresseri *of the St. Lawrence estuary, Québec*. Ornis Scand, 1975. **6**: 41-47.
7. Erskine, A.J. and A.D. Smith, *Status and movements of Common Eiders in the maritime provinces*. Pages 20-29. In *Eider ducks in Canada. CWS Rept Ser. 47*, A. Reed, Editor. 1986, Canadian Wildlife Service: Ottawa.
8. Barrow, B. and P. Hicklin, *Aerial surveys for Sea Ducks along the Eastern Shore of coastal Nova Scotia 20 Sept. - 14 Dec. 1996*. Internal Report. 1996, Canadian Wildlife Service: Sackville.
9. Gauthier, J., J. Bédard, and A. Reed, *Overland migration by Common Eiders of the St. Lawrence estuary*. Wilson Bull., 1976. **88**: 333-344.
10. Mawhinney, D., et al., *Status and Productivity of Common Eiders in relation to the status of Great Black-backed Gulls and Herring Gulls in the Southern Bay of Fundy and the Northern Gulf of Maine*. Waterbirds, 1999. **22**: 253- 262.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Semipalmated sandpiper *Calidris pusilla*	Source
Abiotic Factors		
Temperature	- in laboratory, individuals are unable to maintain normal internal temperature below −18° C - nest in sub- to midarctic areas, so > 50% daily energy requirement used in thermoregulation and production	[1] [1]
Salinity	- no information found	
Oxygen	- no information found	
Substrate preference	- spring & fall: stage (flock in preparation for migration) in areas of shallow fresh or salt water & little vegetation, muddy intertidal zones, or along edges of lakes, usually on soft silt/clay mudflats or at junction marsh and tidal flats - winter: areas of shallow lagoons with dead mangroves; also low tidal zone of mudflats on wet or dry mud	[2],[3], [4] [5],[6] [7]
Water current and tides	- no information found	
Cover	- no information found	
Biotic Factors		
Reproduction time	- arrive at breeding grounds in Manitoba and Alaska in last week of May or early June - males normally precede females by less than a week, and set up territories almost immediately, usually same as previous year - most form pairs shortly after arrival - pairs engage for several days in nest-scraping, where males create numerous scrapes - copulation occurs after nest selection by female - first egg may be laid 4 to 6 days after pair formation	[8] [1] [1] [1] [1] [8]
Reproduction habitat	- low and sub-arctic tundra, near water, in river deltas in dry shrubby areas and mixed sedges and grasses - variably drained upland tundra with low vegetation near small ponds, lakes, and streams - moist or wet sedge-grass or heath tundra; sandy areas along rivers; and pond-dotted sand dunes	[9] [10] [11]
Reproduction	- egg laying (usually 4) can be delayed or postponed depending on weather and/or food availability - later arrivals & re-nesting attempts may result in nest initiation in early July, these may be abandoned in late incubation - both sexes incubate, peak hatching occurs normally in second week of July (after 20 days incubation) - parents lead chicks from nest within hours of hatching - fledgling occurs in late July in 16-19 days	[1] [1] [12] [1] [13]
Food & Feeding	- selective but opportunistic feeding on benthic invertebrates (small arthropods, molluscs, & annelids) in fresh or salt water, also some terrestrial invertebrates (insects & spiders) - feed either by pecking or probing depending on type	[1] [1]

	of invertebrates available: tactile probing for burrowers or visual pecking for surface prey - in coastal areas, foraging is usually regulated by the tidal cycle, with most feeding as water recedes and at low tide on mud-silt substrates	 [1]
Migration	- juveniles migrate southward several weeks after most adults, and most overwinter in South America - about two-thirds of all juveniles do not migrate northward to breed as yearlings, but spend boreal summer on wintering grounds -long distance (often transoceanic) between breeding areas in low arctic North America and wintering range in northern South America - birds heading to eastern Artic migrate along the east coast of North America in the spring & return in the fall travelling along the same route mainly over the ocean - in Bay of Fundy, these migrants constitute about 95% of all shorebirds - most departures occur near sunset or at high tide, most migration occurs at night	[1] [1] [1] [1] [14] [1]
Other	- maintenance of populations is chiefly threatened by destruction or manipulation of coastal and inland wetlands, and possibly environmental contaminants - oldest know individual: 12 yrs old	[15] [1]

References

1. Gratto-Trevor, C.L., *Semipalmated Sandpiper*. In *The Birds of North America, No. 6*, A. Poole, P. Stettenheim, and F. Gill, Editors. 1992, The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union.: Philadelphia.
2. Boates, S. and P.C. Smith, *Crawling behavior of the amphipod* Corophium volutator *and foraging by Semipalmated Sandpipers* Calidris pusilla. Can. J. Zool., 1989. **67**: 457–462.
3. Martini, L.P., et al., *Coastal studies in James Bay, Ontario*. Geoscience Can., 1980. **7**: 11–21.
4. Morrison, R.I.G., *Migration systems of some New World shorebirds*. Pages 125–202. In *Behavior of marine animals, Vol. 6*, J. Burger and B.L. Olla, Editors. 1984, Plenum Press: New York.
5. Robert, M., R. McNeil, and A. Leduc, *Conditions and significance of night feeding in shorebirds and other wading birds in a tropical lagoon*. Auk, 1989. **106**: 94–101.
6. Swennen, C. and A.L. Spaans, *Habitat use of feeding migratory and local ciconiiform, anseriform, and charadriiform birds in coastal wetlands of Suriname*. Gerfaut, 1985. **75**: 225–251.
7. Ashmole, M.J., *Feeding of Western and Semipalmated sandpipers in Peruvian winter quarters*. Auk, 1970. **87**: 131–135.
8. Ashkenazie, S. and U.N. Safriel, *Breeding cycle and behavior of the Semipalmated Sandpiper at Barrow, Alaska*. Auk, 1979. **96**: 56–67.

9. Gratto, C.L., F. Cooke, and R.I.G. Morrison, *Nesting success of yearling and older breeders in the Semipalmated Sandpiper* Calidris pusilla. Can. J. Zool., 1983. **61**: 1133–1137.

10. Holmes, R.T. and F.A. Pitelka, *Food overlap among coexisting sandpipers on northern Alaskan tundra.* Syst. Zool., 1968. **17**: 305–318.

11. Godfrey, W.E., *The birds of Canada, rev. edition.* 1986, Ottawa: Natl. Mus. Nat. Sci.

12. Gratto, C.L. and F. Cooke, *Geographic variation in the breeding biology of the Semipalmated Sandpiper.* Ornis Scand, 1987. **18**: 233–235.

13. Gratto-Trevor, C.L., *Parental care in the Semipalmated Sandpiper* Calidris pusilla*: brood desertion by females.* Ibis, 1991. **133**: 394–399.

14. Hicklin, P.W., *The migration of shorebirds in the Bay of Fundy.* Wilson Bull., 1987. **99**: 540–570.

15. Senner, S.E. and M.A. Howe, *Conservation of Nearctic shorebirds, Vol. 5.* Pages 379–421. In *Behavior of marine animals*, J. Burger and B.L. Olla, Editors. 1984, Plenum Press: New York.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Double-crested Cormorant *Phalacrocorax auritus*	Source
Abiotic Factors		
Temperature	- eggs were successfully hatched with incubation conditions of 37.2 degree C and 60-64% relative humidity	[1]
Salinity	- no information found	
Oxygen	- no information found	
Substrate preference	- found in both freshwater and marine habitats preferring moderately shallow waters (< 10 m) - common in Musquash, observed in 1999 at Five Fathom Hole and Musquash Ledges	[2] [3]
Water current and tides	- no information found	
Cover	- no information found	
Biotic Factors		
Reproduction time	- egg laying begins in late April or early May	[4]
Reproduction habitat	- require undisturbed nesting sites with a convenient food supply - do not venture far from nesting colony - after paring builds tall stacked nests out of whatever plant material they can find, seaweed and other coarse vegetable matter placed on a rude foundation of small sticks - nest in colonies: on projecting shelves on the sides of steep cliffs; on level surfaces above the sea wall & preferably near its edge; and in trees 2 to10 m or more in height - breeds from southwestern Alaska & the interior of North America to the Gulf of St. Lawrence & southern Newfoundland, south to the southern United States & the Bahamas	[5] [2] [2], [4] [4] [4]
Reproduction	- lays 3-6 eggs, usually 4-5; bluish white with overlay of chalk-like substance - both parents take part in incubation as well as care for the young - young are altricial (naked & helpless at hatching) - young birds begin to fly after five to six (5-6)weeks	[4] [6] [6] [6]
Food	- predominantly fish, but will take crustaceans, aquatic insects, and plants - feed during the day by swimming and diving for fish - swallow prey whole and usually above water surface	[2] [6] [6]
Migration	- common in summer, rare in winter - in NS first spring migrants often appear in late March; peak migration is mid-April to late May - fall migration begins in August, but the main movement takes place between mid-September & late October - some probably over-winter in southern NS, but the majority migrates to New England and further south to	[4] [4] [4] [4]

	Florida and the Gulf of Mexico	
Other	- feathers are not water proof & birds spend a great deal of time spreading oil from tail base gland over feathers - over 200 seen in Musquash Estuary in 1999 - human disturbance can adversely affect nesting colonies: increased the likelihood of nest abandonment and gull predation - in the Great Lakes, high levels of toxic contaminants, particularly DDE and PCBs, resulted in population declines; toxins in fish bioaccumulate causing severe impacts on health and breeding - threatened by oil spills, gill-net entanglement and toxic contamination. - poisoning by selenium and mercury can take place in environments where these metals occur	[2] [3] [5] [5], [7] [7] [8]

References

1. Powell, D.C., et al., *Incubation of double-crested cormorant eggs (Phalacrocorax auritus).* Colonial Waterbirds, 1996. **19**: 256-259.
2. Associates, Golder, *NB Power Coleson Cove Refurbishment Project: Comaprative ecological risk assessment pf spill of Orimulsion of fuel oil #6 in the Bay of Fundy*. 2002, Report for NB Power.
3. Deichmann, H., *A survey of bird life in the Musquash Estuary on the Bay of Fundy New Brunswick.* Prepared for the Conservation Council of New Brunswick. 1999, Fredericton, N.B. 69 pp.
4. Website, N.S.M.o.N.H., *Birds of Nova Scotia: Double-crested Cormorant (Phalacrocorax auritus) http://museum.gov.ns.ca/mnh/nature/nsbirds/bns0028.htm*. 2004, Nova Scotia Museum of Natural History: Halifax, Nova Scotia.
5. Weseloh, D.V. and B. Collier, *Rise of the Double-crested Cormorant on the Great Lakes: Winning the War Against Contaminants.* In *Great Lakes Factsheet*. 2004, Environment Canada.
6. Ward, E., *"Phalacrocorax auritus" (On-line), Animal Diversity Web. http://animaldiversity.ummz.umich.edu/site/accounts/information/Phalacrocorax_auritus.html*. 2000, Animal Diversity Web.
7. Anonymous, *SPECIES AT RISK PROFILE: Double-crested Cormorant.* Strait Talk: Quarterly Newsletter of the GEORGIA STRAIT ALLIANCE (online), 2002. **8**: 6.
8. Sepulveda, M.S., et al., *Concentrations of Mercury and Selenium in Tissues of Double-crested Cormorants (Phalacrocorax auritus) from Southern Florida.* Colonial Waterbirds, 1998. **21**: 35-42.

Species Life Requirements/Habitats: Musquash Estuary		
Species	Belted Kingfisher *Megaceryle alycon alcyon*	Source
Abiotic Factors		
Temperature	- no information found	
Salinity	- no information found	
Oxygen	- no information found	
Substrate preference	- various aquatic habitats: lakes, mountain streams, coasts, mangrove, tidal creeks, swamps, rivers, garden ponds and calm marine waters - clear still waters needed for feeding, prefers waters that are not overgrown with vegetation - observed in 1999 in Musquash at Negro Brook, Five Fathom Hole Harbour & Frenchman and Burchill Brook	[1] [2] [3]
Water current and tides	- no information found	
Cover	- no information found	
Biotic Factors		
Reproduction time	- seasonally monogamous, pair bonds formed soon after male establishes his territory - in Manitoba around the 2nd week of April beginning breeding season	[1] [4]
Reproduction habitat	- after mating pair builds nest near water, excavating a horizontal burrow, 1 to 2 m in length, in a river bank, gravel pile or similar steep ridge - nest chamber is located at the end of the burrow & lined with regurgitated fish bones or insect remains	[4] [4]
Reproduction	- female usually lays 6 - 8 white eggs - both sexes incubate eggs for 23 to 24 days - young are altricial (naked & helpless at hatching) - both parents tend young, leave burrow at 30 to 35 days	[4] [4] [4] [4]
Food	- feed on fish, diving vertically into water to catch prey - if fish are scarce, will eat mollusks, crustaceans, insects, amphibians, reptiles, young birds, small mammals, and berries - salmonids & other freshwater & diadromous fishes - one pair will take about 6,000 fish in a season	[4], [5] [1] [6] [7]
Migration	- depends on the availability of open water, will stay in an area year round if fishing grounds can be found - appear in Nova Scotia early to mid-April - outbound in September & October	[8] [9]
Other	- pairs maintain territories, often occupying separate territories for nesting and feeding - generally solitary, except during breeding - human activity, e.g. digging of sand & gravel pits, create nesting habitats & may result in population enhancement - does not seem to be as affected as other fish-eating birds by environmental contaminents - common in summer, rare in winter - can be destructive to trout and young salmon in fish	[8] [1] [1] [1] [9] [9]

	hatcheries and rearing ponds	
	- in a US study, methylmercury posed a moderate risk to kingfishers (50% probability of at least 12-28% decline in female fecundity) & PCBs posed little risk (<5% probability of a decline in reproductive fecundity greater than 10% at any location)	[10]
	- both juveniles & adults accumulate metals & radionuclides; cadmium, lead, & cesium-137 in adult birds were below levels associated with toxicity, but concentrations of selenium & mercury were observed at potentially toxic levels	[11]
	- may be used as an endpoint in ecological risk assessments (ERA) because of their high consumption of potentially contaminated aquatic prey	[11]

References

1. Ivory, A., "Ceryle alcyon" *(On-line), Animal Diversity Web:*1999 *http://animaldiversity.ummz.umich.edu/site/accounts/information/Ceryle_alcyon.html.*
2. Hamas, M.J., A. Poole, and F. Gill, *Belted Kingfisher (*Ceryle alcyon*).* The Birds of North America, No. 84. 1994, Philadelphia & Washington, D.C.: The Academy of Natural Sciences & The American Ornithologists' Union.
3. Deichmann, H., *A. survey of bird life in the Musquash Estuary on the Bay of Fundy New Brunswick.* Prepared for the Conservation Council of New Brunswick. 1999, Fredericton N. B. 69 pp.
4. Nature, M.M.o.M., *The Birds of Manitoba Online: Belted Kingfisher (*Ceryle alcyon*) http://www.museevirtuel.ca/Exhibitions/Birds/MMMN/English/a_belted_kingfisher_data.html.* 2004, Manitoba Museum of Man & Nature.
5. White, H.C., *Local feeding of knigfishers and mergansers.* J. Biol. Bd. Can., 1937. **2**: 323-338.
6. Cairns, D.K., *Diet of cormorants, mergansers, and kingfishers in northeastern North America.* Can. Tech. Rep. Fish. Aquat. Sci., 1998. **2225**: 35 pp.
7. White, H.C., *The food of the kingfishers and mergansers on the Margaree River, Nova Scotia.* J. Biol. Bd. Can., 1936. **2**: 299-309.
8. Museum, R., *Birds of Quebec: Belted Kingfisher (*Ceryle alcyon*): http://www.redpath-museum.mcgill.ca/Qbp/birds/Specpages/beltedkingfisher.htm.* 2004, Redpath Museum, McGill University: Montreal, Quebec.
9. Website, N.S.M.o.N.H., *Birds of Nova Scotia: Belted Kingfisher (*Ceryle alcyon*) http://museum.gov.ns.ca/mnh/nature/nsbirds/bns0227.htm.* 2004, Nova Scotia Museum of Natural History: Halifax, Nova Scotia.
10. Moore, D.R.J., et al., *A probabilistic risk assessment of the effects of methylmercury and PCBs on mink and kingfishers along East Fork Poplar Creek, Oak Ridge, Tennessee, USA.* Environ. Toxicol. Chem., 1999. **18**: 2941-2953.
11. Baron, L.A., et al., *Monitoring bioaccumulation of contaminants in the belted kingfisher (*Ceryle alcyon*).* Environ. Monit. Assess., 1997. **47**: 153-165.

APPENDIX 4

List of Participants
Musquash Workshop on Selection of Indicator Species
Selection of key/foundation species

November 3, 2004, Canadian Coast Guard Building in Saint John, New Brunswick.

Collin Arens – Graduate Student, University of New Brunswick, Saint John (UNBSJ)

Les Burridge – Research Scientist, DFO

Maria-Ines Buzeta – Biologist, DFO

Simon Courtenay – Research Scientist, DFO (Moncton)

Hank Deichmann – Naturalist, Conservation Council New Brunswick

Tim Edgell – Graduate Student, UNBSJ

Kats Haya – Research Scientist, DFO

Art MacKay – Executive Director, St. Croix Estuary Project/ACAP-St. Croix

Alison McAslan – Technician, UNBSJ

David Methven – Professor, UNBSJ

Kelly Munkittrick – Professor, UNBSJ

Paula Noel – Graduate Student, McGill University

Gerhard Pohle – Research Scientist, Atlantic Reference Centre

Shawn Robinson – Research Scientist, DFO

Rabindra Singh – Biologist, DFO

Hilary Strong - Student

Mike Strong – Technician, DFO

Dave Thompson – Baykeeper, Conservation Council New Brunswick

Tim Vickers – Executive Director, Atlantic Coastal Action Programme – Saint John

Maxine Westhead – Biologist, DFO (BIO)